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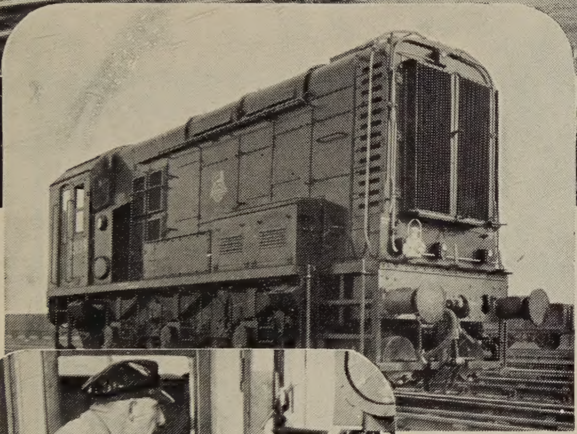
(English Edition)



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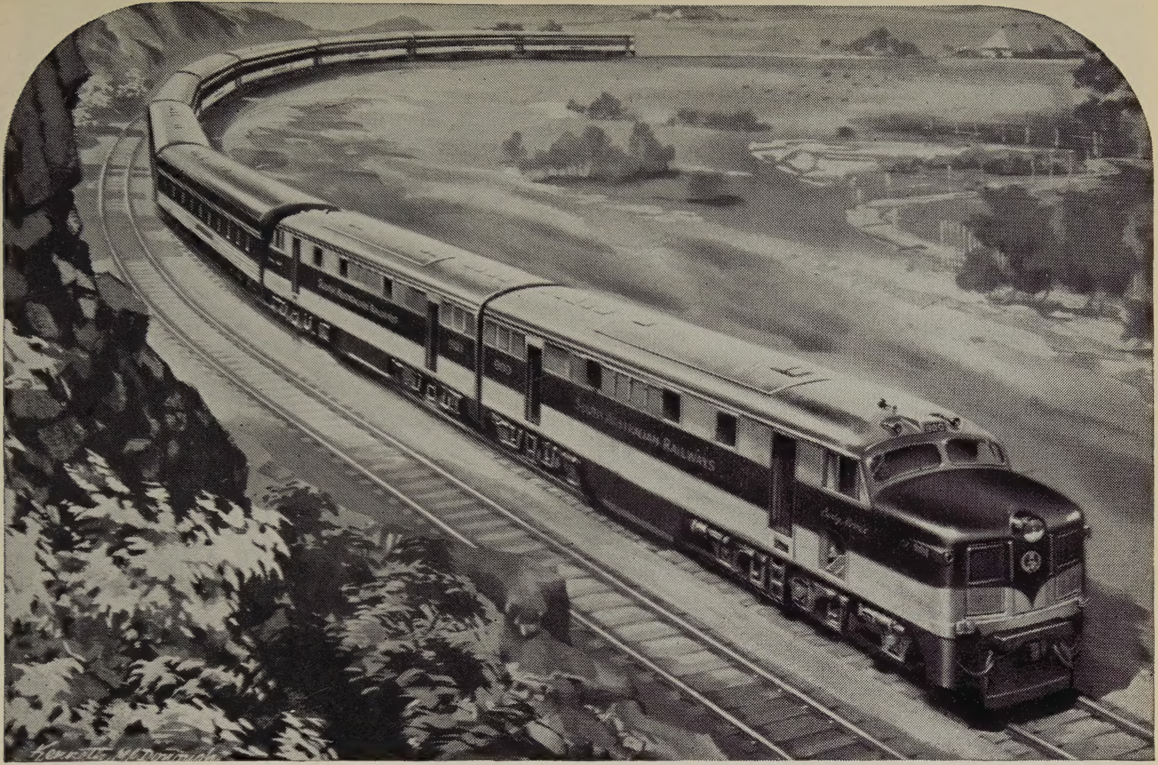


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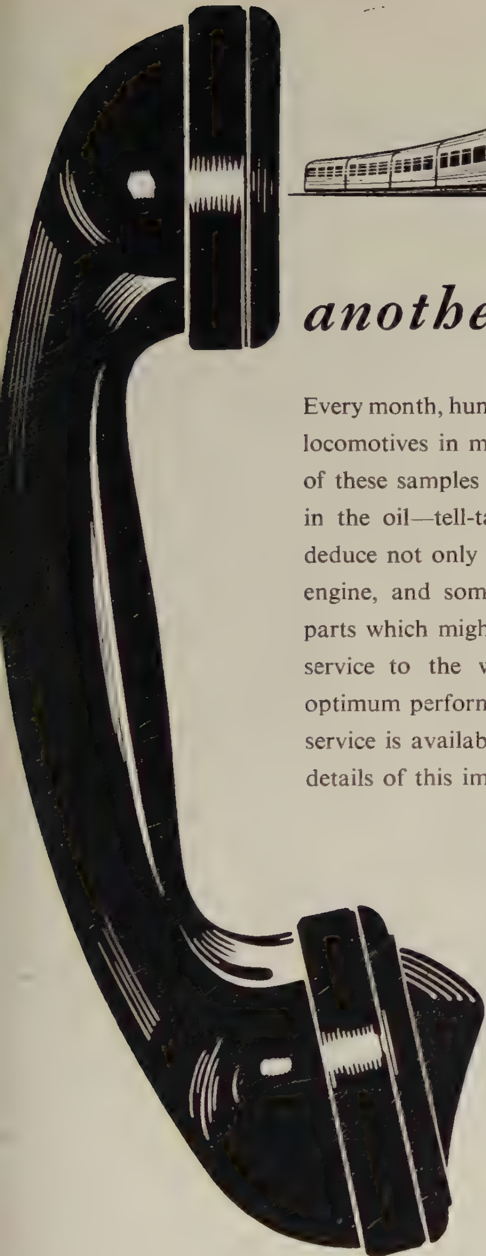

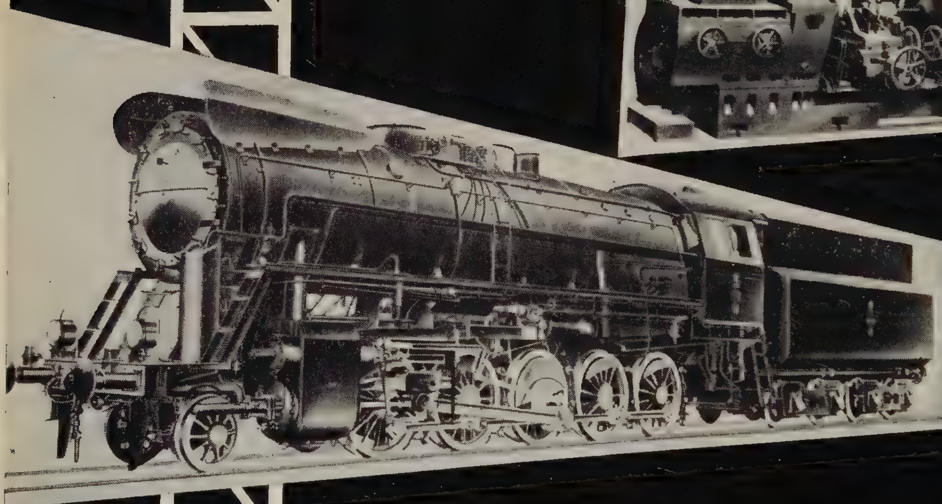

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OF THE

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(ENGLISH EDITION)

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Vol. XXXIII. — No. 5. May 1956.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

SPECIAL ACCOUNTS

summing up the reports on the questions for discussion at the Enlarged Meeting of the Permanent Commission. (The Hague-Scheveningen, 1956)

SECTIONS I and III : Way and Works — Working.

[656 .21 & 656 .25]

QUESTION 1.

Research on the economic usefulness and the technical opportunity to install a third track, serving for common use (banalisation), in addition to sections of double track lines with heavy traffic, instead of installing two double track lines on such sections.

Consequences of the installation of a third track for use in either direction on the conditions necessary to insure the safety of train movements.

SPECIAL REPORT,

by E. Tenti,

Ingénieur, Inspecteur en Chef du Service du Mouvement des Chemins de fer de l'État italien,

and A. Riggio,

Ingénieur, Inspecteur en Chef du Service de la Voie des Chemins de fer de l'État italien.

FOREWORD.

This question was covered by the two following reports :

Report (America [North and South], Australia [Commonwealth of], Burma, Ceylon, Egypt, India, Irak, Iran, Republic of Ireland, Japan, Netherlands, New Zealand, Norway, Pakistan, South Africa, Sudan, Sweden, United Kingdom of Great Britain and Northern Ireland and dependent overseas territories), by V. J. M. de Blieck. (See *Bulletin* for February 1956, p. 95.)

Report (Austria, Belgium and Colony, Bulgaria, Cambodia, Czechoslovakia, Denmark, Ethiopia, Finland, France and French Union, Germany [Federal Republic], Greece, Hungary, Indonesia, Italy, Luxemburg, Poland, Portugal

and overseas territories, Rumania, Spain, Switzerland, Syria, Turkey, Viet-Nam and Yugoslavia), by E. TENTI and A. RIGGIO. (See *Bulletin* for April 1956, p. 323.)

The object of this special report is to sum up the two reports and set out the conclusions to be drawn from the enquiries carried out by the reporters in the different countries consulted.

In principle, when it becomes necessary to modify substantially the equipment of a railway line which has reached the limit of its capacity, it is essential above all that the solution decided upon will enable the line not only to cope with present requirements or those now developing, but also with those which may arise in the future.

On the other hand, the limiting of the cost of equipping and maintaining the lines is one essential objective which must never be lost sight of; it is therefore necessary to reconcile as far as possible the requirements of the operating and of economy. This is why the modification of an overloaded railway line is one of the most delicate problems with which the Railway Administrations can be faced.

At the present time, the Railway must operate as economically as possible in order to be able to compete with other methods of transport. In particular, the quest for greater efficiency of the lines by making use of modern techniques, which make it possible to increase the capacity at less cost than constructing additional tracks is the constant preoccupation of the Companies.

In the United States for example, in the last decades much thought has been given to the possibility existing on multiple track lines to reduce the number of tracks as a result of applying recent signalling improvements.

The object of the present study is to investigate the economic usefulness and technical advisability of constructing a third track, arranged for common user, on sections of double track lines with very heavy traffic, instead of making four tracks.

In this study, by « third track » must be understood an additional line alongside a double line, between two stations, or between a station and a branch line which is not part of the station over which the trains run.

I. Characteristics of sections with a third track in common user on the different railway systems.

According to the information received, at the present time, on the different Railways, there are about 350 km (227 miles) of lines with three tracks. However, most of these sections, on account of their arrangements and the method of operation, should be considered as two separate sets of lines lying side by side, one being a double and the other a single track line, rather than a single three track line dealing with a common traffic, which is more precisely the subject of the present report.

As regards lines of this latter type, which include a third track in common use, the tables given in Appendices A and B of the present report sum up the characteristics of the different sections now in service or being provided.

In addition to the sections of line given in these tables, new « three track » projects are under study, covering two sections of 13 and 15 km (8 and 9.3 miles) on the French Railways (Aulny-Mitry and Orry-Creil), a 14 km (8.6 miles) section on the Spanish Railways (Las Matas-Villalba) and a 28 km (17.4 miles) section on the Indian Railways, all of which have a daily traffic of the order of 180-220 trains; in the case of the Indian section a maximum of 28 trains per hour is considered.

When examining in Tables A and B the volumes of traffic on the different sections of lines, it should be recognised first of all that in the United States of

America three track installations are used when the daily number of trains is of the order of 50 to 100, whereas it is the practice in other countries to make or study such installations on lines where the traffic is considerably higher (more than 200 in most cases, and up to 400 trains).

As regards the number of trains per track sections are concerned, it will be seen that they are generally very short, most frequently only a few kilometres long, except in the United States where the lengths vary from 14 to 45 km.

The number of trains per day, the lengths of the sections and the distribution of the traffic over the day are shown in figures 1 and 2.

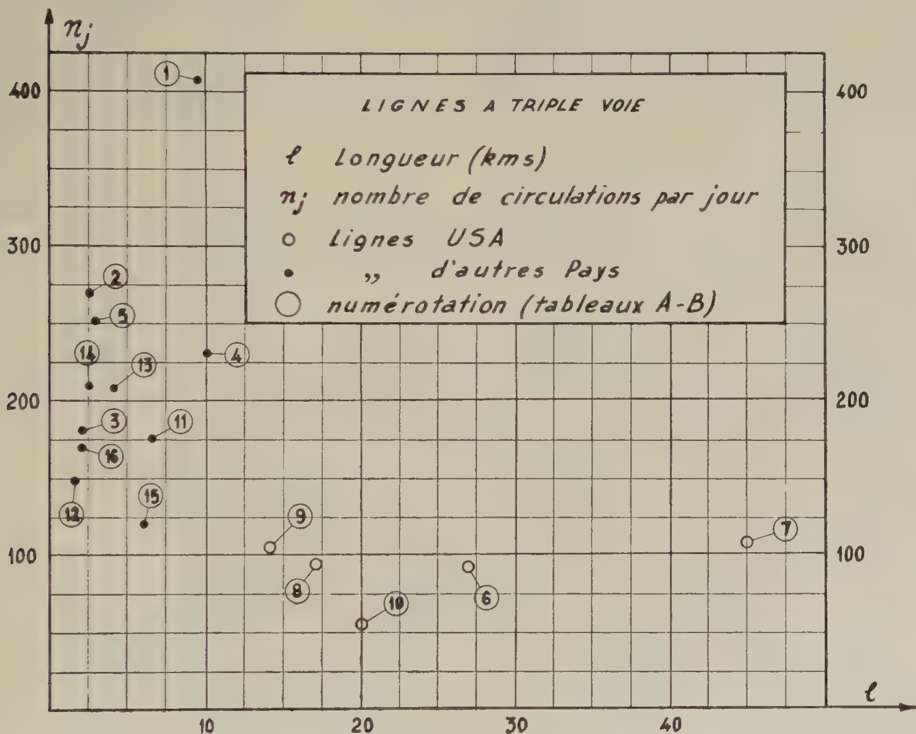


Fig. 1.

Lignes à triple voie = three track lines. — Longueur (kms) = length (km). — Nombre de circulations par jour = number of trains per day. — Lignes U. S. A. = U. S. A. lines. — Lignes d'autres pays = lines of other countries. — Numérotation (tableaux A-B) = numbering (tables A-B).

hour, on certain American three track lines we find maxima of 6 to 8 trains per hour at peak periods, whereas on other lines of the United States and in general on the other Railways, the peaks are considerably higher, and are 14 to 20 trains per hour in most cases.

As far as the lengths of these three

In figures 3, 4 and 5 we have shown respectively a sketch of the three track Ludwigsburg - Bietigheim (Western Germany) line, a sketch of the three track Clybourn-Wilmette section of the Chicago-Winnetka line (U. S. A.) and a graph showing the trains using this latter line.

II. Considerations which in practice determined the choice between the two solutions « three tracks with common user » or « four tracks ».

Characteristics and cost of equipment required.

1. *Traffic and operating needs.*

The problem of tripling or quadrupling a line should only arise after all possibilities of increasing the output of the existing double track line have been exhausted or set aside in view of the characteristics of the existing traffic or that foreseeable in the future.

In general, it may be stated that it is a question of sending over a given line a number of trains such that the two tracks cannot cope with them without undue delays, but looking at it more closely it will be found that it is necessary to complete this definition of the problem. In effect, whereas the automatic block makes it possible to send an extremely high number of trains per day over a double track section (for example on the metropolitan lines), we find on the other hand that on the lines

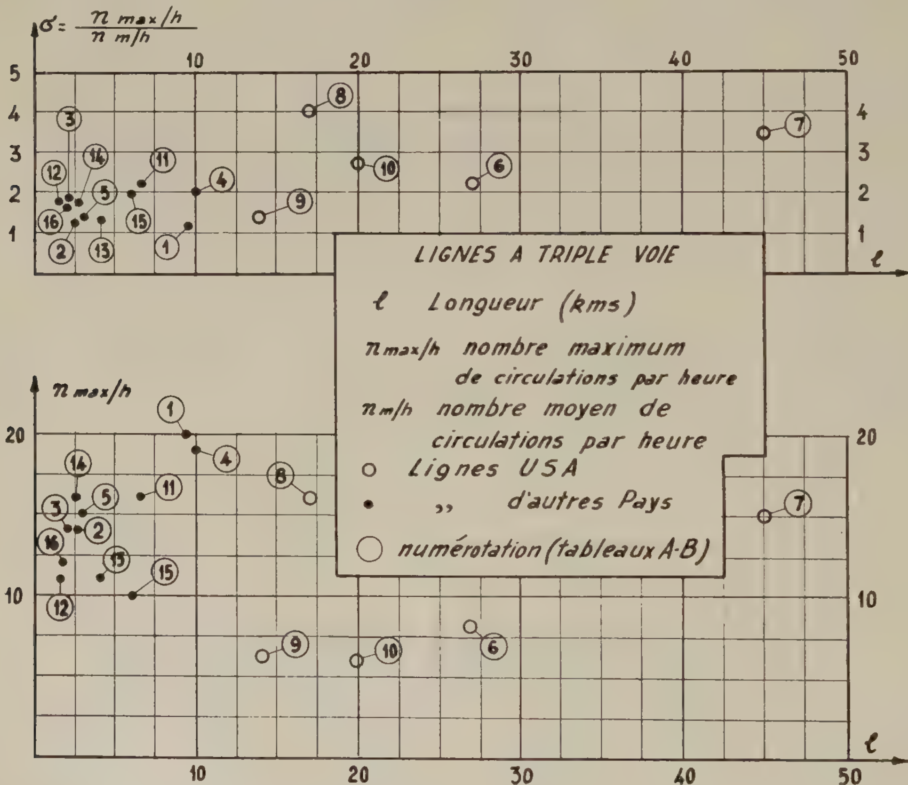


Fig. 2.

Lignes à triple voie = three track lines. — Longueur (kms) = length (km). — Nombre maximum de circulations par heure = maximum number of trains per hour. — Nombre moyen de circulations par heure = average number of trains per hour. — Lignes U. S. A. = U. S. A. lines. — Lignes d'autres pays = lines of other countries. — Numérotation (tableaux A-B) = numbering (tables A-B).

LUDWIGSBURG-BIETIGHEIM (W.).

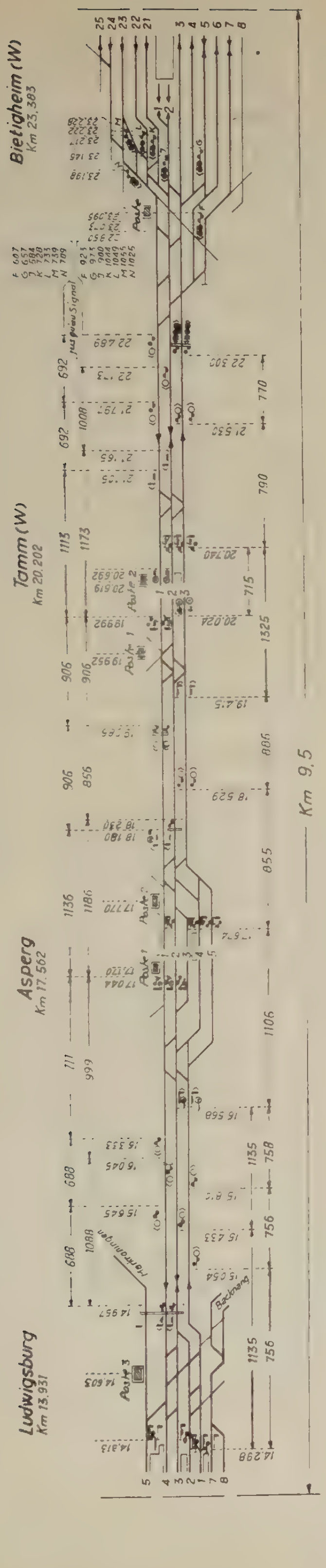


Fig. 3.

of the Railways where it has been considered necessary to increase the number of tracks on sections run over by only 150 to 300 trains a day, or even fewer (American lines).

From these actual figures, it can already be deduced that on the lines of Railway Ssystems, where the character of the traffic is often heterogeneous, the number of trains is not the only problem. It would appear more correct to say that the problem « three track » or « four track » arises as soon as the traffic reaches a certain volume *and the number of trains become such that it is necessary for trains to pass each other whilst running if serious delays are to be avoided.*

Obviously, it is above all the fact that it is the differences in the speed of the fast and slow trains which explains the provision of a third track on certain American lines over which there are not many trains, even at peak periods (see Table appendix B).

In general, the examples of a third track given on the various Railways correspond to common sections between junctions where groups of trains in the same direction occur at very short intervals and a suburban traffic uses the same lines as the long distance traffic; other cases are due to the necessity for separating the freight trains, locomotives, etc., from the faster trains.

As regards the amount of traffic, a very important factor to be considered is the distribution of this traffic over the 24 hours at more or less irregular intervals; in the different cases considered in practice, the ratio between the maximum volume per hour and the average volume oscillates from 1.12 to 4 (see fig. 2). It is obvious that the maximum number of services per hour is the determining factor for the load index of the line.

As far as the choice between the solutions « three track » or « four track » is concerned, the respective situation, dur-

ing the day, of peak traffic in both directions is the first point to be considered.

On the Ludwigsburg-Bietigheim line, for example, it was stressed that the relief given by the third track in common user would have been even greater had not the traffic been equally great in both directions at the same periods, which fact leads to operating difficulties on this line similar to those experienced on single lines. In spite of these difficulties, common user has given good results. In comparison with the former situation, when the third track was used in one direction only (up gradient), it has been estimated that the true daily capacity is increased by 60 %. It must be noted, however, that this increase is due to the adoption of three measures simultaneously: electrification, the automatic block over short sections, and common user of the third track. If other information were available, which is now lacking, it would still be very difficult to decide what proportion of the increased capacity was due to each of these improvements.

On the three track Wiesbaden Hbf-Wiesbaden Ost line, the greater part of the traffic being normally absorbed by the two tracks for one direction only over short sections, the traffic which had to be sent on the third track consisted of sudden rushes of trains in the same direction at close intervals. The increase in the real hourly capacity after the third track was put into common user compared with the double track is estimated as 33 %.

In general, the Administrations agree that the solution « three track » instead of « four track » may be considered from the operating point of view when traffic peaks do not occur at the same time in both directions.

According to the replies received from European Administrations, the solution « three track » should be more advisable for short sections; in the United States, it is also used for longer sections but with daily traffic smaller, except for high hourly peaks on a few lines only.

Finally, an examination of the data given in the table *Appendix A* shows that :

— the maximum percentage of daily services using the line in common user is 28 $(100 \frac{117}{407})$ on the Ludwigsburg-Bietigheim line, and 25 $(100 \frac{50}{200})$ on the Houilles-Sartrouville line;

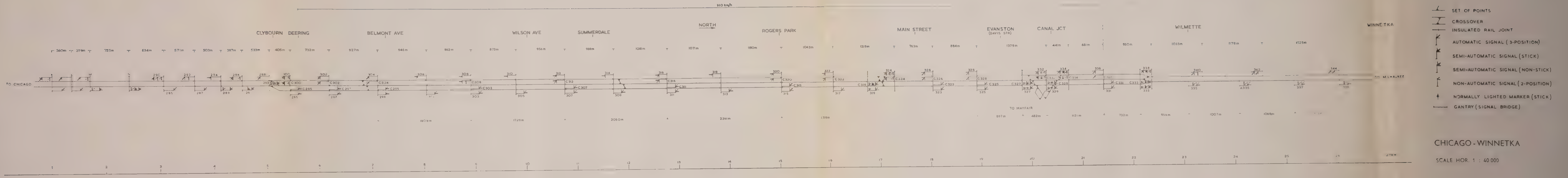
— the gap between the real user of the third track and the theoretical user represents 13 % $(100 \frac{50}{372})$ of the daily services on the Ludwigsburg-Bietigheim section:

— lay-bys representing 10 % $(100 \frac{20}{200})$ on the Houilles-Sartrouville line.

2. — *Characteristics of the equipment of a three track section to meet operating requirements and capital cost compared with quadrupling.*

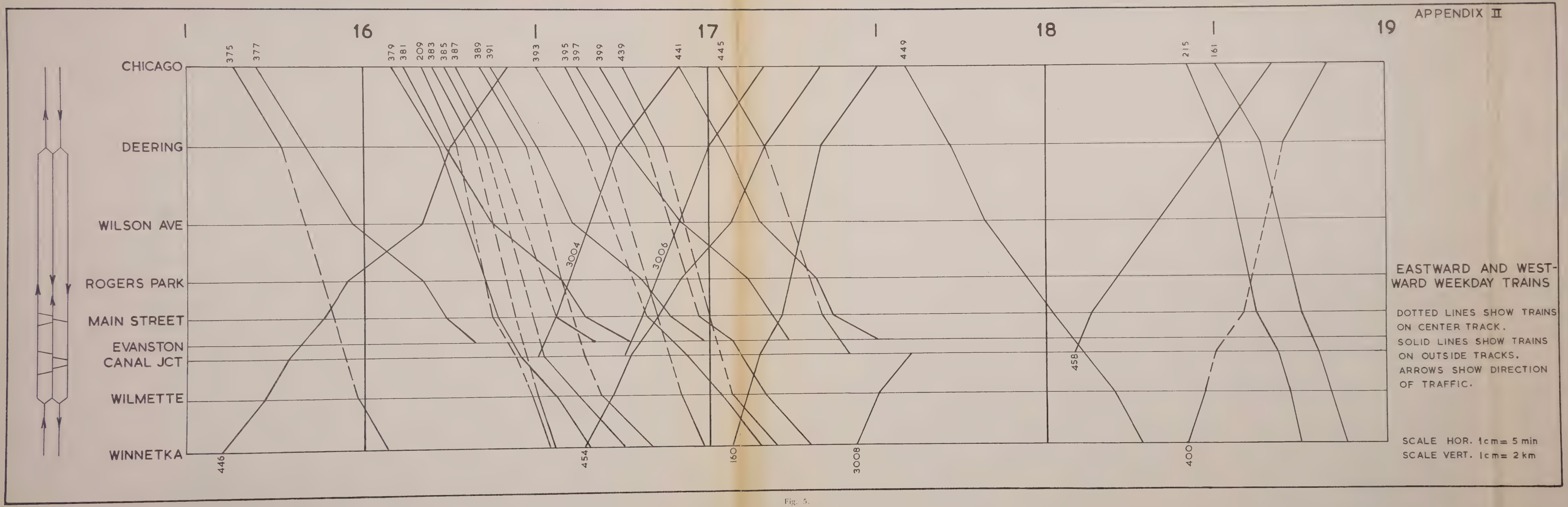
In the installations reviewed, it was usually the centre track which was put into common user, as from the operating point of view this reduces to the minimum any trouble with the train routes when transferring from one track to the other. It is only in special cases that this rule has not been followed, for example when the local installations of the intermediate stations being all situated on the same side, there is interest to arrange the movement of the slow trains on one and the same side to help shunting; provided that this traffic can be worked entirely on one track, or if need be with the assistance of the adjoining track.

The solution « third track at one side » is in principle cheaper than the solution



160 km/h
CLYBOURN
DEERING
BELMONT AVE
WILSON AVE
SUMMERDALE
NORTH
ROGERS PARK
MAIN STREET
EVANSTON
(DAVIS STR)
CANAL JCT
WILMETTE
WINNETKA
TO CHICAGO
TO MILWAUKEE
TO MAYFAIR
SET OF POINTS
CROSSOVER
INSULATED RAIL JOINT
AUTOMATIC SIGNAL (3-POSITION)
SEMI-AUTOMATIC SIGNAL (STICK)
SEMI-AUTOMATIC SIGNAL (NON-STICK)
NON-AUTOMATIC SIGNAL (2-POSITION)
NORMALLY LIGHTED MARKER (STICK)
GANTRY (SIGNAL BRIDGE)
CHICAGO - WINNETKA
SCALE HOR. 1 : 40 000

Fig. 1.


APPENDIX II
16
17
18
19
CHICAGO
DEERING
WILSON AVE
ROGERS PARK
MAIN STREET
EVANSTON
CANAL JCT
WILMETTE
WINNETKA
375
377
379
381
209
383
385
387
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391
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395
397
399
439
441
445
449
215
161
3004
3006
446
454
160
3008
458
400
EASTWARD AND WESTWARD WEEKDAY TRAINS
DOTTED LINES SHOW TRAINS ON CENTER TRACK.
SOLID LINES SHOW TRAINS ON OUTSIDE TRACKS.
ARROWS SHOW DIRECTION OF TRAFFIC.
SCALE HOR. 1cm= 5 min
SCALE VERT. 1cm= 2 km

Fig. 5.

« third track in the middle » concerning the cost of changing an existing double track line.

It is generally recognised that the maximum capacity of the line is obtained by making connections at suitable places between the track for one direction only and the track in common user, and that such connections can be run through at as high a speed as possible. In addition, it has often been recognised as indispensable to construct avoiding lines, besides such connections for the stopping freight trains.

As regards the centralised control, it is interesting to note that certain sections of the line (Ludwigsburg-Bietigheim for example) cope with a very high traffic without being equipped with centralised control, but it has been recognised that the adoption of this method produces further advantages in view of the fact that it is necessary to transfer the trains from one track to the other and to carry out crossings on the line in common user.

As regards the cost of the necessary rearrangements, some interesting data collected in connection with some of the practical cases investigated, make it possible to establish the ratio between the cost of tripling and quadrupling.

a) In the case of the Ludwigsburg-Bietigheim section, account must be taken of the fact that there was already a third track; to put this into common user it was only necessary to adapt the entries to the stations and the signalling. In this case, therefore, common user gave a very cheap solution, compared with quadrupling; this was the chief reason why it was given the preference.

Nevertheless, the expenditure, which would have been necessary, for both solutions « three tracks » or « four tracks », starting from a double line (including alterations to stations, signalling and automatic block equipment) have been estimated as follows :

— Third track in common user . . . . 9 440 000 D.M.
— For four tracks . . . . 12 200 000 D.M.

The cost of the two solutions are therefore in the ratio of $\frac{9.44}{12.20} = 0.77$, which would be higher if centralised control were fitted on the third track.

b) The cost of making a third track in common user on the section Wiesbaden Hbf-Wiesbaden Ost (Western Germany) including the alterations to stations, the automatic block and the signalling was 1 210 000 D. M. (427 000 D. M. being for the signalling alone). Quadrupling, with the same automatic block equipment and connections between the tracks in the same direction at the Mühlthal junction would have cost about 2 million D. M.

The ratio between the cost of the two solutions is therefore $\frac{1.21}{2} = 0.6$.

c) In the case of an existing four track project for the Dusseldorf Hbf-Duisburg Hbf (16.3 km - Western Germany), the difference in cost between the two solutions « three track » and « four track » was calculated; it was small for the reasons given hereafter : existence of a wide enough bed for four tracks and simplification of the connection at the entry to Duisbourg station with quadrupling compared with the tripling solution.

The ratio between the total cost of « three track » and « four track » was as follows :

— Alteration of the double track section into « three track », with common user, automatic block, central control post (without centralised control) :

— for the signalling	3.6 M D.M.
— for the permanent way . .	4.9 M D.M.
	8.5 M D.M.

— Making the double line « four track », with automatic block, without common user, and with no central control post :

— for the signalling	3.4 M D.M.
— for the permanent way . .	6.6 M D.M.
	10.0 M D.M.

Ratio of cost $\frac{8.5}{10}$ = 0.85, a figure which would be still higher if centralised traffic control were installed on the third track.

d) In the case of an existing project for the Pioltello - Treviglio section (20.7 km - Italian Railways) in view of the fact that :

— it is possible to place the third track in common user in the middle and consequently will be necessary to modify considerably the existing track installations and equipment of the four stations on the line;

— that the carrying out of this work on a line run over by very heavy traffic would increase the cost;

— that it would not be particularly costly to make four tracks, especially as this could be done without modifying the existing installations and without disturbance to the working;

— on the basis of sufficiently detailed calculations, the ratio of the estimated cost of the two solutions « three track with common user and C. T. C. » and « four track » is

$$\frac{3\,140 \text{ million lires}}{4\,330 \text{ million lires}} = 0.72.$$

e) In the case of lines in the U. S. A., Japan and Holland, according to the information received it is only possible to make a theoretical comparison of the cost for a 10 km section of line, for example, without any bridges nor removal of any buildings, and without electrification; the average length of the block sections has been taken as 2.5 km and group of four connections every 5 km.

From figures supplied in reply to the questionnaire, it appears that in the case described above the cost of the « three track » solution might vary between 0.77 and 0.97 compared with the « four track » solution. It must be pointed out, however, that these percentages are theoretical and if other factors, of cost, which are to be normally considered in practice (bridges, removal of buildings, electrifications, etc.), were taken into account, the ratio between the costs might be appreciably lessened.

f) It may be concluded, that for the different practical examples studied the ratio of the cost of « three track » and « four track » vary from 0.6 to 0.85.

We think that in certain cases this ratio might be smaller and even fall below 0.6; it must normally be so for example in the case of sections of double line where there are special conditions that would mean that the construction of two further lines would be extremely cosly (embankments and much constructional work, very costly land values) whereas « three track » would avoid or substantially reduce such exceptional costs.

3. — *The operating balance sheet.*

a) It may be affirmed that from the operating point of view, the economic value of turning a double line into three or four tracks, from the point of view of the existing traffic lies essentially in the reduction of slowing down or stopping trains to wait for other trains and the consequent reduction in train-hours on the line.

In this connection, the replies received for the different practical examples considered did not give any precise details on the results obtained or estimated. It must be remembered that most of the installations concerned go back a certain

number of years and one of the hardest things to estimate in comparing the different cases of arrangements and operating are the actual number of stops and waits required with each of the solutions in question.

In addition, on most Railways the average cost of a train-hour is not calculated, and on the other hand, the cost of stopping a given type of train varies too much (according to the method of traction, type of engine, composition of the train, conditions on the line, etc.) for any useful average values to be obtained.

Moreover, if the number of train-hours is the determining factor as regards train staff costs and the amount of traction and rolling stock required, these costs are not entirely proportional to the number of train-hours owing to the fact that, especially on short runs, the staff and rolling stock requirements are not in practice affected by any modification, necessarily limited, in the journey time.

For these reasons no precise factors are available allowing from the economic point of view a comparison of the working of the lines under the different hypotheses of double, three and four track, on the basis of the train-hours, number of stops, etc.

b) Another important economic factor results from the possibility of increasing the traffic on the line turned into a three track or four track line, and in particular of diverting to it those trains which formerly had to be run on lines with less favourable technical characteristics.

c) Savings in the station and signalbox personnel are linked up above all with the existence or not of the automatic block, centralisation posts and C. T. C., and naturally differ considerably according to the number and size of the stations and signal boxes involved.

d) As regards maintenance costs, the table given in figure 6 is of the greatest interest. Relating to the French Railways, it gives for a 6 km long line the comparative

Maintenance costs.

	Double track with automatic block (6 km section)				Three tracks one with common user and C.T.C. (6 km section)				Four tracks with automatic block (6 km section)			
	Permanent way	Signalling	Catenary 1 500V	Total	Permanent way	Signalling	Catenary 1 500V	Total	Permanent way	Signalling	Catenary 1 500V	Total
Maintenance staff : — hours . . . . (per annum)	22 600	960	3 500	23 910	31 500	1 680	5 000	38 180	38 700	1 800	6 500	47 000
— wages . . . . (per annum)	7 800 000	380 000	1 400 000	9 580 000	10 900 000	670 000	2 000 000	13 570 000	13 400 000	720 000	2 600 000	16 720 000
Maintenance of installations . (materials)	8 500 000	250 000	430 000	9 180 000	10 800 000	500 000	650 000	11 950 000	12 800 000	500 000	860 000	14 160 000

Fig. 6.

maintenance costs for a double track with automatic block, three tracks with third track in common user with C. T. C. and four tracks with automatic block.

An examination of this table shows the following ratio between the hours worked by the maintenance staff and the costs (wages and materials) for the three solutions :

— number of hours worked .	1 : 1.59 : 1.96
— cost of wages	1 : 1.42 : 1.74
— cost of materials	1 : 1.03 : 1.54

III. Consequences of adopting a third track in common user upon the conditions normally imposed to assure the safe running of the trains.

In this connection, the Administrations in their replies gave some details about the signalling system and safety regulations used on their lines.

As regards signalling and the operating regulations, the following facts should be stressed :

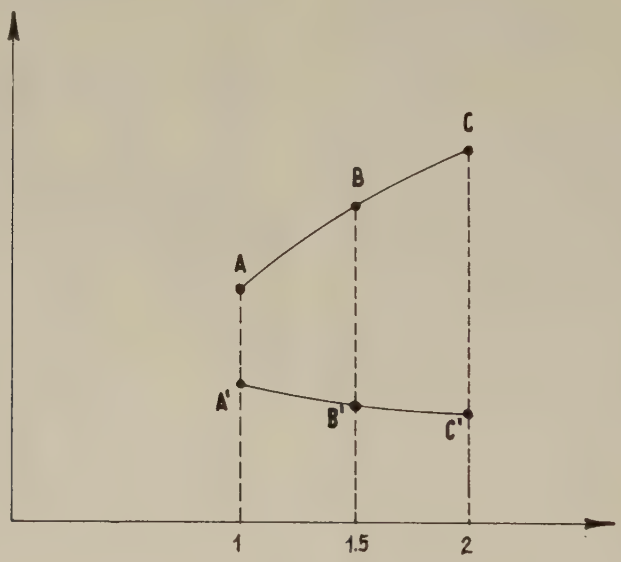


Fig. 7.

The total annual cost for wages and materials would be in the ratio of 1 : 1.37 : 1.63.

For the ratios of cost per unit of transport (ton-kilometre, axle-kilometre), the above figures must be further divided by the volumes of traffic corresponding to the three cases under consideration compared with double track. If these volumes are taken to be in the ratio 1 : 1.5 : 2, we get the diagrams shown in figure 7, A B C for the total costs, and A′ B′ C′ for the cost per unit of transport.

— it is almost the general practice for the Administrations concerned to use, at least on the important lines, home signals preceded by distant signals sited at the braking distances;

— on the great majority of these railways, all the trains, including the freight trains, are fitted with automatic brakes; on certain Railways, a few trains which run at low speeds are exempt from this rule;

— several Administrations have already

introduced, at least on their main lines or in the case of the trains running at the highest speeds, locomotive cab signals or else devices to brake the trains automatically.

In principle, the introduction on a double line of a third track in common user has the obvious consequence of increasing the number of cases in which train routes interfer with each other, and consequently theoretically the risk of trains running into each other. It is obvious that the operating regulations intended to prevent this danger in the case of the simultaneous movement of trains depend essentially upon the value to be given or that can be given, according to the installations and equipment of the lines and trains, to the principle of complete obedience to the signals on the part of the drivers.

Several Administrations, whilst laying down in their regulations the obligation of absolute obedience to the signals by the drivers, consider that other precautions need to be taken in order to minimise to a certain extent the consequences of running past a signal at danger.

In this connection, we may point out that certain Railways consider it advisable to install beyond certain signals throw-out points which are set to dead end short sections when these signals are at danger. The problem is the same as that encountered at junctions and for the latter, in the past, about everywhere protection by derailing device was used; this has now been given up. It is considered that to cause a derailment to prevent trains running into each other is not a good safety measure; the installation of an over-lap section beyond the signal being a much preferred solution.

This latter method is widely used in Europe. Its usefulness is, however, debated by several Administrations, even in Europe, and the modern tendency is to shorten this over-lap section as much as possible and even suppress it altogether in certain cases, in order to avoid any interference with the running of the trains and the working of the stations, preferring to use very complete signalling installations and locomotive cab signals or automatic stopping of the trains.

The making of fly-overs, which avoid any possibility of trains getting in each other's way is only advisable at certain points on the line, chiefly at junctions and the connections between successive sections with different numbers of tracks.

IV. Summaries.

The analysis of the data received and of the considerations set out by the different Administrations in regard to the various traffic and operating situations, the characteristics of the installations, the costs of the equipment and of maintenance, the economic results and safety problems, leads to the following conclusions.

A. Traffic considerations to be taken into account in the study of the various means available to increase the capacity of a double track line.

1. — When on a double-track line with a very heavy traffic, it becomes necessary to contemplate increasing the number of movements or of substantially improving the operating position, it is expedient at the outset to study all the means of increasing the efficiency of the two tracks in order to take full advantage of the potential offered by the line; for instance, improvement of the track lay-out in the stations, provision at these stations of interlocking installations, achieving greater uniformity in speeds, provision of automatic block signalling with short sections, provision of complete signalling schemes, two-way working (banalisation) on one or both tracks of the line.

The efficiency of two-way working requires that, at certain periods, the den-

sity of the traffic in the two directions shall be unequal, either in respect of the number of movements or in the duration of line occupation; it is necessary that traffic peaks in one direction occur at the periods marked by an almost complete lull in traffic in the other direction.

2. — In the case where, owing to the volume and characteristics of the traffic, the above mentioned measures would not offer a satisfactory solution, it is necessary to examine from the three view-points of traffic requirements, technical factors and economic considerations, the value of adopting one or the other of the following two solutions: the construction of a third track, or quadrupling.

These two solutions have one factor in common — one track reserved for each direction of movement, allowing a same basic traffic; to compare the two solutions, it is therefore necessary to take into account the movements it is considered desirable to transfer from these tracks.

3. — In examining the movements in the one direction over a heavily used section of line, one can have either a mixture of trains of widely varying speeds, a situation characteristic of the majority of railway routes, or groups of trains at close intervals in the same direction, which, independent of differences in speed, occur at the same time on the section. The necessity for using the two tracks for traffic in the same direction arises from the fact that the number of trains running in the peak periods exceeds in time occupation the operating capacity of one track, after due allowance has been made for the necessity of not excessively sacrificing the running of slow trains by holding them for unduly long periods and at frequent intervals.

Variations in the speed of the trains constitute an important factor in requiring on certain sections of line an increase in the number of tracks to allow the overtaking, without stopping, of slow trains by the faster trains.

4. — The choice, from the traffic point of view, between the two solutions — « three tracks » or « quadrupling » involves the examination of the characteristics of the traffic at peak periods in the two directions taken together.

Movements can comprise an unbalanced pattern with peaks exceeding the capacity of one track and which occur always in one direction only (either in a permanent direction — up gradient for example — or in opposite directions but at differents periods). In this situation the provision of a third track (respectively without two-way working and with two-way working in the second) offers, in principle, a satisfactory solution. Overtaking without stopping is practicable in one direction only if the third track is not equipped for two-way working, or if it is so equipped, it becomes practicable in the two directions but at different moments of time.

On the contrary, if traffic peaks, each exceeding the capacity of one track, occur at the same time in both directions of movement, quadrupling is, in principle, the most likely solution as it alone will allow of overtaking movements at the same time in both directions. With this situation, a third track in common user could be contemplated in certain circumstances and with certain limits of traffic, but it would be necessary to carry out on this track true crossing movements as on a single-track line.

5. — On any track used in one direction only, the *theoretical track capacity* is determined by the time taken to pass through the longest block section as measured in time. In practice, the mixed nature of the traffic (variations in speeds and in the priority of trains) and ouf of schedule running, as can always arise, make it necessary to regard the *true capacity* as being substantially below (average value 0.7 to 0.8 of the theoretical capacity); time losses occur in actual traffic conditions through the need to give second place to slow and

less important trains in relation to the faster and more important trains using the same track (cases of overtaking either as provided for in the timetable or as necessitated by trains running out of course).

6. — When a second track is available in one direction, this permits at least of doubling the initial capacity, and, by a careful allocation of the fast and slow trains on the different tracks, it can even lead to a better user of the two tracks considered together; it is for this reason in the case of quadrupling a double track line that the operating capacity can be more than doubled.

7. — With a third track, the degree of the increase in capacity is related to the nature of the movements using the third track; it varies according to whether these consist either of groups of trains in the one direction at close intervals (the situation most favourable to high capacity) or of numerous movements in the two directions, which in practice gives rise to the difficulties normally met with on single-track lines. For this reason, the increase in capacity with a third track can only be measured in relation to the different situations and then only approximately: in certain cases it can reach more than half the pre-existing capacity of the line, consequent on the possibility of carefully allocating the fast and the slow trains between the tracks.

8. — In regard to the actual use of the tracks for a given traffic, quadrupling, in principle, allows of a higher degree of specialisation, while on a line with a third track, the necessity to divert trains from one track to another, according to circumstances, and even contrary to the booked working arrangements, is generally more frequent.

The necessity of diverting trains from one track to another, and, in the event, of undertaking on the track equipped for two-way working true crossing movements, as on a single-track line, makes it essential above all else to provide on the third track a complete and rapid system of regulating, which alone allows of substantial flexibility in working, reflecting itself in an increase in operating capacity.

B. Examination of the characteristics of the facilities necessitated by traffic considerations.

9. — With the solution « quadrupling », the necessity of diverting trains from one track to the other used in the same direction being a less frequent event, crossovers will, in general, be provided only at stations. In the specific case of a section of line with four tracks, where mixed working according to circumstances over the two tracks in the same direction has to be provided for, it will be useful to locate these tracks next to each other and to install some additional crossovers between stations.

10. — With the solution « three tracks », it is generally the view that the centre track should be the one equipped for common user as this reduces to a minimum conflicting movements. The third track placed « outside » may be preferable in specific situations, when the slow trains are on one and the same side of the line in order that they can run alongside the station facilities at intermediate points and to facilitate shunting of the trains. In such a case it should be possible in principle to run this traffic on the third track alone, or with the use of the adjacent track for one direction only.

11. — On a line with three tracks, in so far as the diversion of trains between the one-way tracks and the track in common user (« voie banalisée ») is concerned, it is necessary to divide the track into independent sections in such a way as to allow of operation by sectional two-way working (« banalisation partielle »); it is desirable for this purpose to install

between the one-way tracks and the track in common user, connections with a small angle of turn-out so as to avoid the need for unduly severe reductions in speed by the trains passing through them and to allow these trains, if possible, to run through them at the maximum speed permitted on the less favourable of the two tracks concerned.

Sidings have to be installed where it is necessary to consider holding trains near the crossings and at convenient locations.

At junctions where a direct connection to the track in common user would give rise to fouling movements, it will be usual to have recourse to a fly-over or burrowing junction.

12. — As the cross-overs on the track in common user constitute converging junctions, their frequent use requires, in the interest of safety, that there should be absolute confidence in the rigid obedience to signals; this is why, on lines with a track in common user, it is necessary to attach the utmost importance to the provision of a system of signalling giving full and clear indication to the drivers, and to the development of other apparatus capable of ensuring absolute obedience to signals, such as cab signals or automatic train control.

13. — Since it is particularly necessary, in operating with three tracks, to avoid all unnecessary loss of time — whether it be in the selection of the track to be used, in the determination of the crossing places, or in the general regulating of the traffic — automatic block signalling and centralised traffic control (C. T. C.), capable of effecting at the maximum speed remote indication and control, are to be recommended.

14. — The regulating is again improved by making available to the dispatcher the most complete and up-to-date apparatus, such as automatic train describers (or automatic graph recorders), radio communication with the drivers of trains.

15. — In general, quadrupling can be planned without C. T. C. as less frequent intervention is then necessary for train regulating purposes.

C. **Economic considerations.**

16. — Three tracks, above all when there is a two-way track in the centre, can render necessary consequential major alterations in the lay-out of the existing tracks and signalling. These alterations, in that they are carried out on a line already conveying heavy traffic, may result in an increase in the cost of the scheme.

On the other hand, quadrupling, or a third track laid outside, can be planned and constructed, in certain cases, with a minimum of alterations and of difficulties on the double-track line already in service.

17. — The ratios between the costs for the installation of a third track and for quadrupling naturally vary according to local conditions. In the determination of these costs and their ratios, it is necessary in the first place to take into consideration, on the one hand, local geographical conditions, which according to circumstances will make the quadrupling easy or difficult, and, on the other hand, the lay-outs more or less complex as the case may be, at the stations to be adapted. The ratio between these costs for the two solutions, in the cases investigated, varied from 0.6 to 0.85, but it could, in exceptional situations, take values outside these limits.

18. — The economic interest, for the existing traffic, of the tripling and the quadrupling of a loaded double track line results from the reduction in the slowing down of trains and in the detention of trains at signals. A further important economic factor is that of the possibility, in some cases, of diverting to the line considered trains which formely had to be

run on lines with, from the technical point of view, less favourable characteristics.

19. — For the comparison between the provision of a third track and quadrupling, it is also necessary to take into account time losses on the third track in common user arising from possible opposing crossing movements.

20. — In practice, the inter-dependence of the many factors which are involved in the efficiency and regularity of the service makes it very difficult to give a precise estimate in advance of the results to be expected from one or the other of the two solutions under examination. One method, for example, lies in establishing graphically for each of the two solutions theoretical timetables based on traffic requirements and on the operating possibilities offered by the lay-out, and then to compare the results obtained, taking into account as far as possible the ability of each to deal with out-of-course working conditions.

From this comparison, theoretical data can be ascertained in respect of the number of train-hours, and from these calculated, with due allowance for effective utilisation, the expenditure in terms of vehicle-days, the use of motive power, train crews, etc.

21. — The economies in staff at stations and in signalling are above all related to the adoption of centralised signal boxes at stations, of automatic block signalling and of centralised traffic control, with remote control of points and signals. With this last mentioned installation, which in certain cases allows of the achievement of very substantial economies in staff at stations and on signalling duties, it is, however, necessary to take into consideration the possible need to retain at various points staff who can take the requisite action when incidents of all kinds occur.

In general, the estimates in respect of expenditure on staff at stations and for signalling duties can be established in advance for the different solutions examined, with a considerable degree of approximation.

22. — In regard to maintenance expenditure on way and works, it is equally possible to establish in advance estimates sufficiently accurate for the two solutions — the provision of a third track and quadrupling. It will also be necessary to take into account the expected requirements in staff and equipment in the light of the nature and arrangements of the installations, and according to the annual user of each track, expressed, for example, in :

$$\frac{\text{total ton-kilometres}}{\text{kilometres}} \quad \text{and} \quad \frac{\text{train-kilometres}}{\text{kilometres}}.$$

23. — On the basis of operating expenses determined as above and of capital charges (interest and depreciation) it is possible to proceed to calculate the total annual expenses for each of the two solutions contemplated, and finally to estimate in approximate terms the expenses per unit of movement and per unit of traffic.

D. Limits to the application of a third track in common user (triplement avec banalisation).

24. — The solution « three tracks », which, in principle, is less costly than quadrupling, can only be considered if the traffic peaks present certain clearly defined characteristics.

Even if traffic conditions are in favour to « tripling », the quadrupling renders more easy the making of, and adherence to timetables and ensures a greater capacity, advantages which may lead to it being given preference from the operating point of view, the more so if account is taken of future needs.

APPENDIX.

TABLE A. — CHARACTERISTICS OF LINES WITH A THIRD TRACK IN COMM

Railway Administration	Three track section under study		Length km	Position of the track with common user in relation to the other two tracks	Number of intermediate stations		Averag length of sectio between t adjacen sidings km
					With sidings	Without sidings	
Deutsche Bundesbahn	In service	(1) Ludwigsburg-Bietigheim	9.5	In the middle	1	1	3.15
	Third track being made	(2) Wiesbaden Hbf-Wiesbaden Ost	2.5	In the middle	—	—	—
Belgian National Railways	In service	(3) Genval-La Hulpe	2	At one side (on the same side as the local stations in order to facilitate shunting the trains)	—	—	—
	Third track being made	(4) Brussels-Hal	9.9	At one side (in order to avoid the platforms of intermediate stations)	1	1	3.3
French National Railways	In service	(5) Houilles-Sartrouville	3	In the middle	—	—	—

ER IN SERVICE OR BEING MADE IN WESTERN GERMANY, BELGIUM AND FRANCE

ax. speed km h	Maximum speed on the connections between the line in common user and the lines for one direction of traffic only km/h	Maximum gradients on the line both directions of running		Signalling		
		Up	Down	Type	Number of intermediate speeds between maximum speed and stop	Average length of signalling sections km
) to 100	40 to 65	10 ‰ (11.66 ‰ over 166 m)	down-gradient (14.28 ‰ over 175 m)	Light and Semaphore	3 (30 - 40 - 60 km/h)	0.8 — 1.00
85	85	6.25 ‰	—	Light	1 (30 km/h)	0.950
(on tracks in one ction only) (on track h common user)	40	12.4 ‰	down-gradient 7.4 ‰	Light	Various values (figures showing tens of Km/h)	1.00
(on tracks in one ction only) (on track n common user)	40	4.7 ‰	down-gradient 3.8 ‰	Light	Various values (fig. showing tens of Km/h)	1.250
(on tracks in one ction only) (on track n common user)	80	2 ‰	—	Light	1 (80 Km/h)	1.2

Railway Administration	Number of services on the line each day : normal days / peak days							Special feature the traffic on three track sec
	Up			Down			Total on the line	
	Passenger	Freight and loco-motives	Total	Passenger	Freight and loco-motives	Total		
Deutsche Bundesbahn	112 / 120	72 / 83	184 / 203	114 / 122	74 / 82	188 / 204	372 / 407	The traffic is v heavy in both di tions at the sa times of day: gradient on Bietigheim-Ludv burg run increa the journey tir in this direction
	134 / 134	—	134 / 134	134 / 134	—	134 / 134	268 / 268	It is necessary to c with very he peak traffics the same directi especially at cert hours from W baden Hbf (ab one train every t or three minut
Belgian National Railways	70 / 70	20 / 20	90 / 90	70 / 70	20 / 20	90 / 90	180 / 180	Traffic peaks at a given period are one direction or provision has b made for deal with peak tra of 20 trains the same direct during a period 2 hours, such tra running at cl intervals.
	According to estimates after electrification							
	98 / 98	17 / 17	115 / 115	98 / 98	17 / 17	115 / 115	230 / 230	It is necessary cope with hea peak traffic in same direction a to let the fas trains run past slower trains dur the run.
	According to estimates after making the third track							
French National Railways	—	—	100 / 125	—	—	100 / 125	200 / 250	Very heavy p traffic in one dir tion in the morn towards Paris, the evening aw from Paris, 50 tra in two hours, ab 10 lay by siding use daily in e direction of r ning.

Number of trains daily using the third track in common user (including trains which only use it for part of their run) : normal days / peak days							Maximum number of services per hour on the line			
Up			Down			Total on the line	Up	Down	Total on the line	On the track in common user
senger	Freight and loco-motives	Total	Passenger	Freight and loco-motives	Total					
63/72	1/7	64/79	25/29	5/9	30/38	94/117	10	10	20	6
46/46	—	46/46	48/48	—	48/48	94/94	—	—	14	5
(According to estimates after installing the third track.)										
(According to momentary needs, especially for goods trains.)							10	4	14	As neces-sary
15/15	2/2	17/17	15/15	2/2	17/17	34/34	13	6	19	7
(According to estimates after installing the third track.)										
—	—	25/25	—	—	25/25	50/50	—	—	15	3

Railway Administration	Basic system for assuring safe running	Regulation of the running of trains and use of the three tracks	Centralised control of points and signals: Technical capacity of the central control post	Centralised control of points and signals: Working part of the central control post	Adoption of any special measures or means to promote better control of the traffic
Deutsche Bundesbahn	Automatic block (manual block in station sections)	Preliminary programme and regulation by dispatching (in carrying out the programme a daily average of 25 trains in each direction of running is moved from one track to another in the section).	—	—	—
	Automatic block	Preliminary programme and regulation by centralised control.	Control by route. Number of orders : 48 Number of announcements : 150 Orders and announcements can be stored.	Maximum number of operations per hour : 24.	Automatic train running recording equipment is on trial. Use is also going to be made of automatic indicators showing the train numbers. There is no radio-communication.
Belgian National Railways	Automatic block	Preliminary programme and regulation by dispatching	—	—	—
	Manual block	Preliminary programme and regulation by dispatching.	—	—	—
French National Railways	Automatic block	Preliminary programme and regulation by centralised control.	Individual control and control of 22 points and 14 signals.	Setting up a route according to its complexity may require 2 to 7 interventions by the operator, who also has to assure at the same time the regulation by dispatching of a section of line without C.T.C. covering in all 60 km.	—

APPENDIX — TABLE B.

Characteristics of lines with a third track in common user in service in the U.S.A., in Japan and in the Netherlands.

ADMINISTRATION	SECTION OF LINE	Length in km	Number of trains per day					Number of trains per hour	
			Ex-press	Stop-ping	Freight	Light en-gines	Total	Aver-age	Maxi-mum
Chicago and North Western Railway System	*a)* Elmhurst-West Chicago . . . . . (6)	26.5	24	53	12	—	89	3.7	8
	b) Clybourn-Barrington . . . . (7)	45.4	55	44	6	—	105	4.4	15
	c) Clybourn-Wilmette . . . . (8)	17.4	61	33	—	—	54	3.9	16
The Pennsylvania Railroad Company	*a)* Oakington-Bush River . . . . . . (9)	14.0	68	7	27	—	102	4.3	6
	b) Bucyrus-Crestline . . . . (10)	19.6	18	—	34	—	52	2.2	6
Japanese National Railways	Nakama-Chikuzan-Ueki. . . . . (11) (figures relating to traffic of the year 1944)	6.4	—	35	138	—	173	7.2	16
Netherlands Railways	*a)* Tilburg-Tilburg Siding . . . . . (12)	1.5	10	71	60	5	146	6.1	11
	b) Eindhoven-Woensel . . . . . . (13)	4.0	23	80	92	12	207	8.6	11
	c) Bilthoven-Den Dolder . . . . . . (14)	2.5	13	148	47	6	214	8.9	16
	d) Onnen-Groningen (cours.) . . . . (15)	5.8	33	22	32	31	118	4.9	10
	e) Groningen (cours.)-Groningen . . (16)	1.7	33	61	37	38	169	7.0	12

25. — On lines carrying a very heavy traffic the « third track in common user » may be preferred, in the case where the characteristics of the traffic being suitable, to the quadrupling if the cost of the latter much higher which is normally the case above all owing to the particular configuration of the ground. The most characteristic examples are the following :

a) sections common, near to large town, with traffic peaks of different speeds but only in one direction at a time, with high cost of land or major civil engineering works necessary with quadrupling : a typical case of sections of line common to suburban and main line traffic with peaks in one direction only in the morning, at midday and in the evening;

b) short sections interposed between four-track sections, such as for the passage of major engineering works too expensive to quadruple.

26. — In addition to the cases cited, the provision of a third track, with or without common user (according to circumstances) may be sufficient for traffic requirements on sections of line carrying a very mixed traffic (substantial variations in train speeds) where it is specially important to allow the overtaking without stopping of the trains.

27. — The fact that many Railways only had for a long time an insufficient experience of the potentialities offered by centralised traffic control, both from the traffic and technical points of view, can have led more easily in the past, to neglect the solution « third track in common user ». At present, in the light of technical progress, the risk of a C. T. C. installation being put out of service accidentally is slight, and this cannot constitute a factor sufficient to reject this solution.

28. — In the future, the provision of a third track in common user will, it seems, be adopted more frequently than in the past even if its scope for application to lines with very heavy traffic remains limited in general to relatively short sections with special characteristics.

SECTION II. — Locomotives and rolling stock.

[**621** .431 .72]

QUESTION 2.

In a system of standard, narrow or broad gauge lines which has Diesel traction for shunting and for main line working, what are the conditions governing :

1) the choice of the characteristics and kind of transmission ;

2) the most economical organisation, maintenance and operation.

Research into savings that might be possible in comparison with steam traction.

SPECIAL REPORT,

by R.F. Harvey,

Chief Operating and Motive Power Officer, British Transport Commission.

This question was covered by the two following reports :

Report (America [North and South], Australia [Commonwealth of], Burma, Ceylon, Egypt, India, Irak, Iran, Republic of Ireland, Japan, New Zealand, Norway, Pakistan, South Africa, Sudan, Sweden, United Kingdom of Great Britain and Northern Ireland and dependent overseas territories), by R. F. Harvey. (See *Bulletin* for February 1956, p. 129.)

Report (Austria, Belgium and Colony, Bulgaria, Czechoslovakia, Denmark, Ethiopia, Finland, France and French Union, Germany [Federal Republic], Greece, Hungary, Indonesia, Italy, Luxemburg, Netherlands, Norway, Poland, Portugal and overseas territories, Rumania, Spain, Sweden, Switzerland, Syria, Turkey, Viet-Nam and Yugoslavia), by R. Biais. (See *Bulletin* for March 1956, p. 233.)

I. Introduction.

The questionnaire for Question 2 (Section II) of the Enlarged Meeting of the Permanent Commission of the International Railway Congress Association was sent to 113 Railway Administrations, from 36 of which replies were received.

Mr. Biais, Chief Engineer of the S.N.C.F., Reporter for the French speaking countries received 26 replies; myself, the Reporter for the English speaking countries : 10.

The two reports show that in the majority of cases, it was very difficult for the Railway Administrations to give a complete reply to the many questions asked them.

Under the heading « Economic enquiry » for example, the replies to the questions asked were in many cases very short, or completely lacking.

The use of Diesel traction on the railways is in fact relatively recent, and although several countries and a certain number of Administrations have already

been using various types of Diesel locomotives for shunting or train services for some time, sufficient data is not yet available to throw light upon the multiple aspects of the problems arising or which may arise when steam traction, known to railwaymen throughout the world for nearly 150 years, is replaced by Diesel traction.

II. Choice of characteristics.

a) *Power of the locomotives.*

It is generally agreed that for equal power a single locomotive costs less to buy and maintain than two separate locomotives, each of half the power. It should however be noted that other factors which limit the possible power of a single locomotive also affect the type chosen, in particular the state of the permanent way, the axle load, and the loading gauge.

For this reason, most Administrations prefer locomotives of average power, which can be coupled together as multiple units when tonnage and speed requirements render this necessary.

b) *Types of locomotives to be provided.*

In the case of train services, although it is advisable to reduce the number of different types of locomotives, a single type of locomotive cannot satisfy the requirements of the main lines and secondary line services, owing to the differences in traffic and the economic need to obtain the best possible use of each unit.

The same applies to shunting locomotives, the work required of which can be grouped into the three following categories :

— shunting in small stations and shops;

— hump shunting and branch line services;

— heavy shunting and transfer of rakes.

The table hereunder gives the powers generally accepted for such locomotives.

The radius of operation of the locomotives used for train services is generally determined either by the longest non-stop run without refuelling, or the longest distance between refuelling points. Most often the radius of operation of the locomotive is about 800 to 1 000 km (500 to 620 miles).

As regards shunting locomotives, these can work between 3 and 16 days on end according to the Administrations and types of locomotive.

c) *Axle arrangement.*

The axle arrangements of the locomotives used on the main lines vary considerably, chiefly on account of the admissible axle loads and the tractive effort required.

On light tracks, the type A1A-A1A is

Type of service	Locomotive power
Main lines — fast or heavy traffic	1 500 to 2 000 HP (or even over).
Main and secondary lines — mixed traffic	750 to 1 500 HP.
Secondary lines (and if necessary shunting)	under 750 HP.
Shunting :	
Heavy shunting and transfers	600 to 800 HP or over (1 000 to 1 600 HP in the U.S.A.)
Hump shunting	350 to 600 HP.
Small stations and sheds	under 200 HP.

that most often used. The Bo-Bo and Co-Co types are widely used on standard tracks.

There is a strong concensus of opinion on the Continental railways that the B.B. type is the most economical up to 1 700 HP as regards wear of the permanent way and tyres, whilst other Administrations prefer the Co-Co and even the 1Co-Co1 type.

However, to date insufficient information is available to determine which axle arrangement assures the maximum economy as far as maintenance of the permanent way is concerned.

Certain heads of the Permanent Way Department are of the opinion that in the light of our present knowledge, if the rails are submitted to a load (in tons) per axle of more than 4 1/2 times the diameter of the wheels (in feet), fractures of the rails may occur in the end owing to the excessive shear stress and plastic flow in the rail head.

With shunting locomotives, the most widely used axle arrangements vary from the type B to the type D according to the rated power; however there are also some BB locomotives which certain Administrations prefer to the types with coupled axles either because of the method of transmission chosen, or because of their less harmful effects upon the permanent way.

d) *Number and type of engines installed.*

In general, in view of the fact that the thermic engine rarely breaks down, a single engine is preferred by the Administrations even in the case of powers of the order of 1 500 to 2 000 HP, in spite of the cost and weight of these latter engines. In the case of electric transmission, this solution is considered more economical than having two engines of less power with their generators, etc., on one locomotive.

On the other hand, on locomotives with hydraulic drive, as for example the type V.200 of the D.B., it has been found advantageous to fit two 1 000 HP engines, each driving separate transmissions.

Two-stroke engines have been used in Sweden, Luxemburg, the United States, Republic of Ireland and Great Britain, as well as on the Ö.B.B. and the N.S.

None of these Administrations has expressed any opinion on the suitability of this type of engine for railway traction. The Republic of Ireland and the British Railways in particular have not yet had sufficient experience with this type of engine to be able to express any opinion on the question.

When specialised labour is available or can be trained so that the maintenance work is properly carried out, it is not considered desirable to sacrifice the efficiency of the Diesel engine. When possible it is considered useful to carry standardisation as far as possible to cover the greatest number of components according to the various ratings.

It may however be desirable on certain railways where the recruiting of specialised labour for the maintenance and storage of exchange parts raises serious problems, to look into the possibility of using a low efficiency Diesel engine of a simple and well proved type.

e) *Driving compartments.*

A single driving compartment is preferred in the case of shunting locomotives.

As far as the position of this single driving compartment is concerned, some railways prefer it to be in the centre, and others at one end of the locomotive.

On railways where the loading gauge is limited, it is not possible to fit the driving compartment in the centre, and the only alternative is to have it at one end of the locomotive.

On the line locomotives, it is necessary to have a driving compartment at each

end, especially when it is possible to work with single units.

f) *Choice of drive.*

The fields of user of mechanical and electrical drives are becoming fairly well defined.

Mechanical drive is suitable on engines of 200 HP or less; on engines of 800 HP or over, electrical drive appears to be the best.

Between these two powers, the hydraulic drive appears to compete with the other two; compared with electrical drive in particular, it is cheaper to buy and about the same as regards convenience of driving, regularity of working and efficiency. When the engine has to drive more than two axles, electrical drive however undoubtedly gives the best results.

On locomotives with rigid wheel base, Jackshaft drive from the gearbox to the final drive by side coupling rods is preferred.

In the case of electrical drive, the traction motors are generally coupled permanently in pairs in series both on line and shunting locomotives. Coupling the motors in parallel is preferable when circumstances warrant the extra expense this involves.

g) *The dead man's handle.*

The majority of Administrations stipulate the use of a dead man's handle, but some of them do not consider this to be necessary in the case of shunting locomotives.

The fitting of such a device increases the safety, in particular on units driven by one man, or on locomotives where it is necessary for the second man to leave the driving compartment at regular intervals to deal with the engine, or steam generator, etc. In addition, it prevents the driver from leaving his controls whilst the locomotive is running.

h) *Heating the trains.*

As most passenger coaches are fitted with steam heating, the system adopted almost universally is the oil-fired boiler fitted on the locomotive itself.

The power of the steam generator, the volume of steam required per hour and the amount of water which can be carried are difficult problems to solve.

On railways where electrification is under consideration, one solution might be to convert the passenger stock to electric heating and to install auxiliary Diesel-generator groups instead of the boiler on the locomotive.

Certain Administrations have built vans fitted with oil-fired heating boilers, in spite of the difficulties this involves at the ends of the line or when the train has to be divided up at a junction.

i) *Fire fighting equipment.*

A large number of Administrations prefer automatic equipment or remote controlled equipment in addition to hand operated fire extinguishers on the large units, the portable equipment not being considered sufficient except in the case of the small units.

As carbonic acid gas dissipates very rapidly in air, the D.B. and S.N.C.F. now prefer to use a water atomiser driven by a hand pump and supplied with water from the cooling circuit.

It is however considered that this type of equipment would not be suitable on Diesel-electric locomotives because apart from the damage caused by the fire, the electrical equipment might also suffer serious damage.

III Organisation of the service and operating.

a) *Driving the locomotive.*

In most cases, there are two men on line locomotives and only one man on shunting locomotives.

Apart from helping the driver, the second man on the line locomotives looks

after the heating boiler, and checks the power equipment periodically.

In general, the drivers of Diesel locomotives are attached to the Locomotive Running Department (Motive Power).

Certain Administrations also make use of the station staff to drive small locomotives in the stations.

b) *Recruiting and training the locomotive staff.*

Most Administrations train their steam locomotive drivers to drive the Diesel locomotives. In the U.S.A., Diesel drivers are recruited amongst the firemen or the men working as assistants on the Diesel locomotives. On a few Administrations, the drivers are recruited from amongst the maintenance shop staff.

Training includes a course on the engine and the transmission, and their working, and on driving.

According to the organisation adopted on each railway, these courses are either held in special centres or in the sheds to which the Diesel locomotives are attached, and are completed by lessons given on the actual locomotives, whilst running, by specially trained staff.

On most Administrations, the drivers are trained to drive all the types of Diesels running on their lines, and can drive the trains on no matter what route, provided they have the necessary knowledge of the road.

On Railways where staff, other than registered drivers, drive the small locomotives in the stations, such staff are specially trained and supervised in order to make sure that the locomotives are handled correctly.

c) *Method of working the lines.*

Except in the U.S.A., dieselisation does not appear to have led to any extensive modifications in operating methods on the main lines; there is however a tendency to make the longest possible runs without a change of locomotive in the case of the through freight services.

On the other hand, the inherent advantages of Diesel locomotives have led to considerable modification in the operating of secondary lines on many railways. Amongst other changes, may be noted the use of the same locomotive for the train services and for the shunting and for shuttle services between different intermediate stations.

d) *User of the locomotives.*

Owing to the lack of statistics, few Administrations have been able to supply detailed figures.

From the information collected, it may be concluded as a first approximation that the time locomotives are out of service is at the present time about 20 % and the rate of user is more than 12 hours out of 24.

e) *Improvement compared with steam traction.*

Here again detailed numerical data per type of service are lacking on most Railways, either because no statistical details are available, or because an important change in the traffic has made it impossible to form any precise comparison.

The total figures given however make it possible to state as a first approximation that at least in the case of Europe, compared with the number of steam locomotives required, replacement Diesel locomotives are usually in the ratio of between 0.6 and 0.8.

IV. Maintenance.

a) *Basic criteria.*

The different Administrations base the maintenance of their Diesel locomotives on one of the following three criteria:

— mileage;

— number of hours in service;

— time.

The mileage factor is fairly generally taken into account in the case of line locomotives. It is the prevalent opinion that this factor gives a fair indication of the state of wear of the engine and locomotive, and has the advantage of being easy to follow.

The factor « number of hours in service » is used by certain Administrations for their shunting locomotives.

Finally, the time factor is favoured by several Administrations (in certain cases for inspections only, overhauls still being based on the mileage), in view of the fact that this greatly facilitates the work of the maintenance services as regards drawing up the inspection programme.

In no case is the examination of certain factors such as the oil analysis, the rate of compression, the oil consumption, etc., used alone to determine the intervals between maintenance jobs. These methods, which many Administrations use systematically and which are very valuable, are intended above all to keep a check upon the state of the engine and to complete, by the information they supply, a rational preventive maintenance policy.

b) *Intervals between repairs.*

Between two general overhauls of the locomotive, maintenance generally includes various inspections and overhauls for which a programme is duly drawn up, the nature of which corresponds to an increasingly thorough overhaul.

It is difficult to fix at the present time the periods at which these various operations should take place — the figures given by the Administrations vary by as much as 100 % — this subject is still being developed. It may however be concluded from the data supplied by the Administrations that they all have a tendency to increase these periods but only do so after acquiring sufficient experience of operating the type of locomotive in question. The general opinion is that the most economical maintenance policy is to carry out high class repairs at long intervals.

c) *Quality of the cooling water.*

The use of ordinary untreated water or of softened water for the cooling depends upon the conditions prevailing in the countries concerned, and from region to region of the same country.

Certain Administration add an anti-corrosive product to the water in order to avoid corrosion of the liners.

V. Installations.

a) *Modification of existing installations.*

The installations used for the maintenance of the steam locomotives are not entirely satisfactory for Diesels. Certain sheds can however be modified, by suitable rearrangement of the entry and exit lines (installation of fuel, oil, water and sand supplies) and by providing inspection gantries, installing mobile hoods for drawing off the exhaust gases, etc.

On a certain number of railways however special sheds will be built for maintenance and repairs.

b) *Stocking and distributing the fuel.*

Each Administration provides stocks of fuel at certain carefully selected points on the system and the quantity stocked depends upon requirements and the site chosen for the depot in question.

The capacity of the fuel tanks depends upon requirements, but the following factors also have to be taken into account :

— two or more tanks are necessary at each depot so that while fuel is being issued from one tank, the fuel can settle in the other tank or tanks, the settling period depending upon the size of each tank and the quality of the fuel;

— average and maximum daily consumption;

— constitution of a sufficient reserve of fuel. The distance from the consuming centres to the distribution centres must also be taken into account.

Filtering the oil when it is poured into the tanks, and also between the tank and the locomotive being refueled is most important. A trial on the use of static separators to remove any water and of filters which will remove particles of the order of a micron is in hand on the S.N.C.F.

The oil can be delivered by compressed air when the tanks are air tight or by mechanical pumps.

c) *Precautions to be taken during the winter.*

In countries with severe winters, it is considered desirable to shelter the locomotives either when they are being inspected, or when they are not working.

Heating for the comfort of the staff is necessary under moderate climatic conditions, and in countries where the cold is severe, heating for the protection of the locomotive as well as the comfort of the staff is necessary.

When it is not possible to put the locomotive under shelter, it is necessary to run the engines at intervals in order to prevent the cooling water freezing, especially when the locomotive is stationary in a station, or marshalling yard, etc., at some distance from its maintenance depot.

VI. Expected economies.

a) *Traction Department.*

The chief reasons which led the Administrations to take steps to substitute Diesel traction for steam traction can be briefly summed up as follows:

— increased availability;

— increasing cost of coal and shortage of suitable supplies, together with the fact that Diesel oil is a more economic fuel in certain countries;

— cleanliness;

— improvement of the traction characteristics.

Economies in the use made of the locomotive staff are harder to estimate. On railways where it is the rule that line Diesel-electric locomotives are manned by two men, savings under this heading are due not to the possibility of driving such locomotives by one man, but to the reduction in the number of hours required for the preparatory work at the sheds, due to the fact that the Diesel trains can make long runs without having to change locomotives en route. New Zealand state the resultant saving in staff is estimated at about 20 %. On the other hand, in the case of locomotives driven by one man, the saving in staff is about 50 %. Savings under the headings « Maintenance and Repairs » cannot yet be estimated in view of the fact that the Diesel engines have not yet required a general overhaul.

On the other hand, there has been some additional cost in many cases in making suitable sheds and on installations for stocking the fuel, as well as providing the staff with special tools, etc.: it is not however possible to supply any precise data on this point.

b) *Permanent Way Department.*

As regards the savings, due to dieselisation, on the maintenance of the permanent way, the majority of Administrations state that, as a whole, they are not in a position to give any well founded judgement on this point, though some of them think that a saving, especially on curves, can be expected.

On the other hand, certain officials of the Permanent Way Department have expressed the opinion that powerful Diesel locomotives may prove more harmful towards the track than steam locomotives, owing to their axle loads and the greater stresses they exert on curves owing to their smaller wheels.

In any case, it is generally considered that the use of Diesel locomotives will lead to a reduction in the number of fires along the track.

c) *General balance sheet.*

Certain Administrations have supplied studies regarding the replacement of steam

traction by Diesel traction, but as these are merely estimates, we have not taken them into account in the present report.

SUMMARIES.

1. — The formula according to which the whole power is concentrated in a single locomotive is that which produces the lowest capital and maintenance costs. However, dividing up the power required between two locomotives conduces to more flexible working. Moreover, it is necessary to do so at the present time whenever the power required exceeds 2 000 HP.

Multiple unit locomotives, which can only be run as multiple units, are now in use in the U.S.A.

2. — It is obviously advantageous to reduce the number of classes of locomotives. It is also advantageous to provide standard equipment, common to several classes, at least in the case of the auxiliary equipment.

3. — Under commercial transport conditions as found in Europe, it is difficult for any single type of locomotive to be suitable for hauling all the different categories of trains. It appears necessary to provide one type of locomotive intended for fast or heavy traffic on the main lines (1 500 to 2 000 HP or over), and one or several types of locomotives for mixed traffic on the main and secondary lines (750 to 1 500 HP) and for the traffic on the secondary lines as well as for shunting if necessary (less than 750 HP).

4. — In the case of shunting, for the different kinds of services, there are three corresponding classes of locomotive, the powers of which are:

— for shunting in the small stations and shops: less than 200 HP;

— hump shunting and branch line services: 350 to 600 HP;

— heavy shunting and transferring rakes: 600 to 800 HP.

In some countries, these powers may be exceeded. They largely are in the U.S.A. where they may be as much as 1 000 to 1 600 HP.

5. — The axle arrangement depends upon the permissible axle loads. In the case of the line locomotives, the type A1A-A1A is that most used on light track. The BB and CC types are widely used on standard gauge lines.

Some of the railways on the Continent consider that the BB type is the most economical up to 1 700 HP as far as wear of the track and tyres is concerned, whereas others prefer the CC and even the 1C-C1 type.

However, up to the present, insufficient data is available to determine which axle arrangement gives the greatest saving as regards permanent way maintenance.

In the case of locomotives of average power running at less than 60 km (37 miles)/h, parallel axles from the type B to the type D can be used. In other cases, bogies are preferable.

6. — Diesel engine technique can now provide reliable and powerful engines, and the tendency is to give up the use of two-engined locomotives.

When specially trained labour is available, or can be trained to make sure the maintenance work is properly carried out, it is not considered advisable to sacrifice the efficiency of the Diesel engine.

On some Railways, where the recruiting of trained labour for maintenance and the supply of spare parts present a serious problem, it may however be desirable to look into the advisability of using a simple lower efficiency Diesel engine of a well tried type.

7. — Several Administrations have put into service Diesel locomotives fitted with two-stroke engines. It is however not yet possible to make any statement on the final balance sheet of the respective advantages and drawbacks of two and four-stroke engines.

8. — Having a driving compartment at each end appears advisable in the case of locomotives used for train services. On shunting locomotives, on the contrary, the solution of a single driving compartment is preferred. Certain Railways state that this should be in the centre of the locomotive and others at one end.

9. — The present fields of application of mechanical and electrical drives are fairly well defined : engines of less than 200 HP and more than 800 HP respectively. Between these two powers, the hydraulic drive competes with the other two types. Compared with electrical drive, hydraulic drive is cheaper to buy, and about the same as regards convenience of driving, regularity of working and efficiency. When the engine has to drive more than two axles the electrical drive undoubtedly gives more elegant solutions.

10. — Fitting a « dead man's device » is to be recommended on line locomotives driven by one man. It may also be of value when the locomotive has a crew of two men.

Certain Administrations do not consider it necessary to fit this device on shunting locomotives.

11. — The trains are heated either by steam heating or electric heating, according to the kind of equipment in the rolling stock being hauled.

In the case of steam heating — the most widely used — the steam boiler is preferably installed on the locomotive. The heating boiler-van ought only to be used exceptionally owing to the operating difficulties involved.

12. — Shunting locomotives can be driven by one man. Usually there is a second man to help the driver on locomotives used for train services.

13. — Common user leads to the best use being made of locomotives and staff. It is an advantage for the staff to be trained to drive the different classes of locomotives and railcars.

14. — In the case of secondary lines, when possible it is advantageous to use the same locomotives for the train services and for shunting operations in the stations involved.

It may be of value to modify the method of operating on certain lines, either to improve the service, or to obtain a better user of the locomotives.

15. — It is possible to entrust the driving of the small locomotives to the station staff of the stations where they are in use. This staff must then be trained and supervised, and provision made for carrying out small maintenance jobs on the spot.

16. — In the first stages of dieselisation it is reasonable to count upon 20 % of time out of service and rates of utilisation of more than 12 hours out of twenty-four.

17. — Owing to the greater availability of the Diesel locomotive, it is possible to work an identical service with an appreciably smaller number of locomotives with Diesel traction than with steam traction. Compared with the stock of steam locomotives, the stock of Diesel locomotives replacing them is generally in the ratio of 0.6 to 0.8.

18. — The periods between the different inspections and overhauls can be determined either by the mileage or the number of days or hours in service. The mileage basis gives a fairly close indication of the condition of the engine and the locomotive. The time basis is more convenient to follow for the maintenance services. An intermediate method is to base the inspections on the number of days or hours in service and the overhauls on the mileage.

19. — It is recommended that an analysis of the lubricating oils and a spectographical examination of the ash be made in order to obtain information on the advisability of making an oil change or carrying out preventive repairs on some engine component.

20. — As with other methods of traction, maintenance includes on the one hand preventive inspections, and on the other overhauls according to a predetermined programme. Whether this is based on « mileage » or « time », there is a whole scale of inspections corresponding to the amount of work to be done. Between two general overhauls of the locomotive, the engine is given a part overhaul without being dismantled.

In most cases, the overhaul periods laid down when the Diesels were put into service would appear from experience to be capable of being increased. It appears that the most economic maintenance policy is to make high grade repairs at longer intervals.

21. — Care must be taken to see that the water used for cooling the engine is neither corrosive nor scale-forming.

22. — Provided certain rearrangements are made, it is possible to make use of the steam traction installations. Such rearrangements affect the entry and exit lines (installations of fuel, oil, water and sand supplies) and the sidings in the shed (making inspection pathways, mobile hoods to draw off the exhaust gases, etc.). In mixed sheds, it is recommended that separate installations be reserved for Diesel traction.

23. — The stocking and supplying of the fuel-oil requires at least two tanks, one of which is a spare and settling tank. Expressed in days of average consumption, the total capacity of a distribution centre varies between 20 and 40 days; the settling period varies according to the quality of the fuel-oil. There is a tendency to give up centrifuging the fuel and towards perfecting the filtering methods.

24. — Since the Railway Administrations find themselves obliged to renew a certain proportion of their stock of steam locomotives, it is natural that they should change over to a method of traction which shows operating economies under the following three headings : power, driving costs and shed costs.

a) As regards fuel, the economy depends on the comparative cost of coal and fuel-oil, including taxes. In most cases, especially in the case of shunting, very substantial economies have been recorded.

b) As regards driving staff, the economies are considerable when only one man is needed on the locomotive.

Even in other cases, they are substantial, simply on account of the better user of the staff.

c) As regards shed costs, economies of more than 40 % may be obtained.

25. — Economies under the heading maintenance have been recorded by some Administrations. It is too soon to express a definite opinion on this subject.

26. — Apart from strictly economic considerations, there are others, such as the improvement of passenger transport conditions, the improvement of working conditions for the driving and maintenance staff, and the greater flexibility of working. In African countries, doing away with the perennial problems of water and coal is an appreciable advantage.

27. — At the present time it is difficult to assess the economic repercussions of dieselisation on departments of the railway other than the Locomotive Running Department (Motive Power). In particular, it is not yet possible to say how the permanent way maintenance costs and operating receipts will vary, all other things remaining equal. The considerable reduction in the risk of fires along the tracks can however be mentioned.

28. — In general moreover, the difficulty the Administrations have found in presenting a complete economic balance sheet shows that it is still too early for all the conclusions on the economic aspects of dieselisation to be drawn.

SECTION IV. — General.

[656 .23]

QUESTION 3.

Development of railway tariffs.
Economic justification of these tariffs.
Adjustment of tariffs to the new conditions of the general economic system and to the competition of the other forms of transport.
Function of tariffs in coordination of inland transports.

SPECIAL REPORT,

by L. Antoine,

Directeur du Service Commercial à la Société Nationale des Chemins de fer belges.

This question 3 was covered by the following reports :

Report (America [North and South], Australia [Commonwealth of], Burma, Ceylon, Egypt, Germany [Federal Republic], India, Indonesia, Irak, Iran, Republic of Ireland, Japan, New Zealand, Norway, Pakistan, South Africa, Sudan, Sweden, United Kingdom of Great Britain and Northern Ireland and dependent overseas territories), by Dr O. Maier. (See *Bulletin* for January 1956, p. 1.)

Report (Austria, Belgium and Colony, Bulgaria, Cambodia, Czechoslovakia, Denmark, Ethiopia, Finland, France and French Union, Greece, Hungary, Italy, Lebanon, Luxemburg, Netherlands, Poland, Portugal and overseas territories, Rumania, Spain, Switzerland, Syria, Turkey and Yugoslavia), by L. Antoine. (See *Bulletin* for February 1956, p. 107.)

A perusal of the reports on this question shows very clearly the great diversity in railway tariff systems throughout the world.

This diversity is particularly marked in the case of freight tariffs.

One general preoccupation has always dominated the problem of drawing up railway tariffs : the need for sufficient receipts to cover expenses judiciously kept within bounds.

However, during the period during which most railways enjoyed a monopoly, the various factors on which the tariff is based have undergone a constant evolution as dictated by national opinions and exigencies. The manipulation of the tariffs solely based upon the final equilibrium of the budget started various degrees of mutual interdependence not only between the passenger and freight sections but also between each of the categories included in one or other of these sections.

In the field of freight tariffs, the differentiation of prices is generally due either to certain relativities of an « ad valorem » character or based upon the principle « make the goods pay what they can afford to pay ».

In the case of both passenger and freight tariffs, with few exceptions there is uniformity of price on all the different itineraries.

In the case of freight tariffs in parti-

cular, the reductions allowed have often been excessive because they have been based in the main upon economic pre-occupations.

The expansion of the « new » methods of transport with their enormous possibilities leading to very active competition, very soon upset the bases of railway tariffs, which had remained more or less untouched until the beginning of the present century.

Although the shock was particularly severe and very considerable efforts were made to restore the position in many countries, it still does not appear that any guiding line can orientate onto a common path the responsible organs of the life of the undertakings in such a way as to solve the problem set, i.e. in adapting the tariffs to the new conditions prevailing in the general economy and to the competition of other methods of transport.

Essential factors of a national character continue, in fact, to bind the undertakings and the consequence is that only very rarely can the tariffs acquire, as they should in view of the disappearance of the monopoly, a more business like character, i.e. be closely bound up with the actual costs.

1. — First of all, mention must be made of the actual statutes of the undertakings, statutes which follow an extensive scale from the State undertaking to the private undertaking of a more or less industrial character, so that the prevailing ideas on the financial objective and the possible intervention of the State in this field are very varied.

It should be stressed moreover that certain railways have very serious financial problems awaiting the attention of their Government.

2. — Moreover, the States themselves have very different ideas of the role to be played by the railway as a public service.

There is for example a great diversity in the case of their legal obligations:

— obligation to carry;

— obligation to operate;

— obligation to apply legally published tariffs.

Most often too State requirements in this connection are stricter in the case of railway undertakings than in the case of other transport undertakings.

3. — On the other hand, there is no uniformity in the behaviour of the different States as regards the road costs falling upon the different methods of transport.

4. — The States also seem to have very varying points of view on the relations between the different methods of transport. Certain countries seem to prefer to let road transport undertakings enjoy complete freedom, whereas others have regulations of various strictness both for water and road transport, from a summary regulation as regards obtaining an authorisation to very extensive coordination, even going as far as obligatory tariffs.

5. — The railways are also fairly frequently more strictly dependent, if not the only ones, on the State, as far as safeguarding by means of the tariffs the interests of the general economy is concerned.

Very often the Public Authorities continue to impose upon the railways, without complete compensation or with insufficient compensation, tariffs of a political character, or of a social character, or intended to subsidize certain branches of the national economy.

The passenger and freight tariffs continue to be mutually complementary in many cases, the deficit from the passenger tariffs being made good by the receipts from the freight tariffs. Obligatory mutual compensation exists between certain categories of freight tariffs.

As a result of these exigencies, it necessarily happens that the freight tariffs, which are generally predominant in the

activities of the undertakings, do not reflect the true competitive capacity of the railway.

6. — As a result of the obligation to carry which continues to bind certain railways, they are not free to select only the profitable traffic like their competitors.

Private transport undertakings, which enjoy practically complete freedom in their business relations, are able to complete their services by making use of the undertaking bound by obligations of a public service in the case of the most costly transport or for safety reasons.

7. — The reactions of the Public Authorities responsible for the national economy are often unfavourable when faced with the evolution of railway tariffs in order to adapt them more closely to the idea of the cost of running the business.

* * *

The observations made above mean that the evolution of the tariffs generally only takes place within the framework of the national policy.

It is therefore almost illusory to try and find in the tariff encyclopedia any common features in the evolution of these tariffs.

Amongst the copious information supplied, it does however seem to us particularly valuable to recall the most striking formulae used to endeavour to obtain, with due regard to competition, a better share of the traffic in general and sufficient receipts.

In Europe, it appears to be the Netherlands Railways who have been able to take advantage of the maximum commercial flexibility.

Mention must be made of the very special character of their general tariffs, both passenger and freight, which are firmly based upon the idea of the cost, and which include, in the case of the freight tariffs, the possibility of making special contracts as rendered necessary by competition.

The French Railways suggest as the ideal situation in the case of the passenger tariffs the covering of the total costs by the full fare scale, reduced fares being intended to acquire a further clientele and cover at least the direct costs involved.

In the case of the freight tariffs, these will be adjusted according to the idea of the cost. They include a maximum and a minimum scale, again with the possibility of making private contracts in certain cases.

The tariffs, moreover, lay down a certain minimum weight according to the nature of the goods in question, which helps in assuring a suitable user of the stock.

The graduation of these scales already appears to be strongly centred on « marginalism ».

In Great Britain, a new system of tariffs is to come into force with the object of introducing strictly commercial principles.

The « ad valorem » classification is to be given up. The rates will be the maximum rates within the limits of which the cost of the transport can be determined upon commercial considerations.

It should be noted that this proposal takes into account the fact that the rates of road haulage firms are not regulated.

The Swedish Railways want to adapt their tariff system to the new competition and relax the principle « uniformity in space and time ».

Other European Railways, in particular the German, Swiss and Belgian Railways, are looking for new solutions which may or may not entail fundamental changes in their present tariff systems, or else are founded upon the introduction of measures of co-ordination affecting, for example, the transport rates imposed upon other methods of transport.

In the U.S.A., those Railways which belong to the A.A.R. in particular, are asking for the repeal of the laws imposing discriminatory regulation between the different transport undertakings, as well as a reduction in the granting of licences for contractual transport undertakings to operate. They insist that greater stress should be laid upon the power of competition in establishing the tariffs.

They are also demanding that no obstacle should be put in the way of suppressing services which show a deficit, and that they should be allowed to make use of other methods of transport under equal terms.

In various countries where the organisation of transport is fairly recent, it appears that the problem raised is not yet of any great importance. As a result, it has been shelved for the time being.

* * *

In view of the above report, we can see no other possibility under present conditions than to submit to the learned discussion of the Congress a small number of resolutions which must of necessity take into account the extremely diverse situations and their evolutionary character.

1) It is essential that the policy of the States regarding the use to be made of railway transport should be defined within the framework of the general national transport policy.

2) The permanent financial soundness of railway undertakings is an objective that must be achieved.

3) It is desirable that in so far as the railways are allowed to suffer from the competition of other methods of transport, they should receive equal treatment as far as possible.

4) In the field of the tariffs, the first objective should be first of all to cover the costs separately in each of the two sections « passenger » and « freight ».

5) The efforts made by the railways to revise their tariffs and bring them in line with the actual costs should be encouraged.

The greater flexibility required in the face of competition should be authorised and facilitated in relation naturally with the factors of the specific costs which must be taken into account.

6) The obligations surviving from the era of monopoly, to the extent that they cannot be cancelled, should be fairly compensated to the profit of the undertakings.

7) Co-ordination measures should be defined within the general transport policy but also taking into account their consequences upon the railways, as well as the special obligations of the latter as a public service and the fact that they cannot act on a strictly business basis like their competitors.

[385 .581 (44)]

The new centralised control of train staff on the S. N. C. F.,

by M. Long,

Ingénieur en Chef, Chef de la Division du Contrôle du Mouvement à la Société Nationale des Chemins de fer français.

Apart from the crews on the actual motor units, trains of all kinds (passenger, freight, etc.) are often accompanied by train staff who travel in the vans, in passenger coaches, even in some of the wagons; the number of such staff, who are attached to the Operating Department on the S.N.C.F., was formely quite considerable, as they played a direct part in the safety of the working; in particular they were responsible for working the screw type hand-brakes. Since continuous brakes have been generally fitted to freight trains as well as to passenger trains, the number of train staff has been considerably reduced, the Operating Regulations having been gradually modified so as to make it possible to suppress them completely. In France, a relatively large number of trains (135 000 km [84 000 miles] per day out a total of 900 000 [560 000 miles] train-km) are already running without any train staff and this number will increase from year to year; these are usually through trains; staff strictly essential for the actual train services will only be retained in the future (checking the passengers, handling luggage and parcels at secondary stations, carrying out shunting operations in intermediate stations and on branches on the open line).

Finally, the number of train staff on the S. N. C. F. which was more than 31 000 in 1938 is now only 12 000, whereas the mileages have varied as follows :

188 million passenger train-km in 1954 compared with 284.6 million in 1938;

50.4 million express goods train-km in 1954 compared with 36.3 million in 1938;

111 million goods train-km in 1954 compared with 116.5 million in 1938;

in all 349.4 million km in 1954 compared with 437.4 million km in 1938.

This staff is distributed amongst 292 localities (average number per locality : 41); the most important locality (Tours) has more than 200 train staff.

That which characterises the train staff essentially is that nearly every one of them carries out a different service and this service changes nearly every day in order to keep within the labour regulations which set very precise limits to the daily working hours and its extent, and make it necessary to bring the men back to their home town very frequently, at least every two days. The problem is further complicated by the fact that such staff is not strictly interchangeable; there are several different grades; in addition, only some are trained to deal with passengers' tickets; some are not

trained to work on railcars or electric trains and carry out the duties of a second motorman, at least capable of stopping the engine should anything go wrong with the proper motorman.

To facilitate control of the staff and increase its output, the train staff is divided into two categories : as large a proportion as possible is included in the rosters which include in principle all the *regular* passenger and freight trains; the second group forms the reserve. The regulation rest periods are generally covered by the rosters themselves; the reserve is used for replacements for holidays and sickness and also for those trains which for any reason, either because their rostering cannot be arranged in advance or because the trains run at such intervals that it is impossible to include them in the rosters (fig. 1).

On the S. N. C. F., on the 22nd May 1955, 8 200 train staff were included in the rosters and 3 800 formed the reserve.

The work to be done by the reserve has therefore to be set out each day, taking into account the trains other than regular which will be run, as well as absences due to holidays or sickness of men from the rosters.

For a long time, the stations at the train staff home towns were responsible for this; a permanent control office was run at each station with specialised staff in important cases and non-specialised staff in other cases; the employee who wanted a day off went to the control office at his home town and they took a man from the reserve to replace him. If this could not be done, he could not have the day off. A station which had to run a special train also advised the local office who provided a man from the reserve if possible; if no one was available, the station helped out the train services by supplying a man from the reserve station staff.

It might happen that there were no train staff living near a marshalling yard; this yard then had to apply to some specified place which was responsible for supplying the necessary train staff; apart from this special case, it was only occasionally that one place had to come to the aid of another place, and this was usually done by transferring the staff for a given period from places with temporarily redundant staff to others where there was a temporary shortage.

This simple system did not always result in a satisfactory user of the staff; although the local controls had at their disposal not only their own reserve staff, but also men in transit from other places who had accompanied a train not included in the usual timetables, these local controls could not have any complete picture of the situation as a whole and only knew the requirements of their own locality.

Long before the S.N.C.F. was formed, the former French companies had studied this problem; this was why the S.N.C.F. as soon as it came into being in 1938 decided to generalise the system of central control of train staff; for this purpose in each of its forty operating regions it set up a central organisation responsible for co-ordinating the work of the local controls; the local controls continued to be responsible for supplying from their reserves replacements made

necessary on account of holidays or sickness of the regular train staff; on the other hand, the optional service was in the hands of the central control; for this purpose, the local controls only made use of a man on a train which was not included in the regular timetable after receiving the assent of the central control; in the same way, the local controls put at the disposal of the central control any available train staff other than those from their own locality; let us suppose for example that with this system there are three stations A, B and C situated or not on one and the same line; if station A, in agreement with the central control has appointed an employee from its locality to work a train from A to B, station B has no right to make use of this employee but has to put him at the disposal of the central control which might make use of him or even send him immediately to station C to take a train from C towards A; the central control attached to the operating department of the region knows in fact what provisions had been made for special trains to leave station C and knowing all the facts could make use of this to return an employee to his own locality at A (fig. 2).

The difficulties experienced by the S.N.C.F. during the war and immediately after it owing to the breakdown of the telephone system made it necessary to scrap the central controls for the time being; these were either suppressed completely or their responsibility reduced to mere supervision of the work of the local controls without any direct intervention in the control of the staff.

As soon as circumstances improved, the question of central control was reopened during the last few years, but in the meantime there had been considerable evolution in the situation; in particular the system of trains without any train staff on them had developed on the S. N. C. F.; the trains accompanied by train staff are usually the regular trains; on the contrary, the special trains seldom have any train staff on them; under these conditions, reserves were hardly needed for any other purpose than to replace those on holiday or sick; their importance has already been very much reduced and will be even more so in the future, and it will become possible to do away with local controls completely and have all the staff directly under the central control.

This system is the one now being progressively introduced on all the Regions of the S. N. C. F. (fig. 3).

For information, the number of spare staff each day at the disposal of each central control is on the average 80; the busiest central control (Lyons) has a reserve of 144 men spread over 7 localities :

Locality	Number of men	
	in regular service	in reserve
Badan	32	12
Chalon-sur-Saône	51	19
Lozanne	13	2
Lyon-Guillotière	66	30
» Perrache	123	74
» Vaise	8	3
Mâcon	9	4
Totals	302	144

ROULEMENT D'AGENTS DE TRAINS N° 500

Région OUEST — Applicable le 22 Mai 1955

Résidence: Alençon

Nombre et grade des Agents en roulement: 9 CTRP/CTR autorisés à l'arrêt des autorails (aux lignes à trafic restreint)

LÉGENDE

- Trains
- $\boxed{2333}$ Haut le pied
- (R) Pause pour repas
- Opérations avant départ et à l'arrivée
- Service de gare
- Réserve à disposition
- (P) Parcours à pied

Jours	Service (0 à 24 h)	Amplitude de la journée de travail et entre deux G.R.P.	À déduire: Coupures	À déduire: Trajet haut-le-pied	Travail effectif journalier et entre deux G.R.P.	Durée des Repos: À la résidence	Durée des Repos: Hors résidence
1	Alençon — semaine sauf samedi: 5255 Argentan 4242	10.00	3.55		6.05		
1	samedi: 5255 R. Sées 1272 Alençon	3.54		0.08	3.46		
2	4242 Le Mans (sem. sf ILF) 1265 Alençon 5255 Argentan 248	11.13	5.01	0.30	5.42		10.20
2	Alençon (ILF) 5255 Argentan 248 Alençon	7.43	2.32		5.11		
3	Alençon — semaine: 5252 Le Mans 4269 Argentan	6.26			6.26		
3	dim. fêtes: RT Le Mans 4269 Argentan	7.04	3.00	0.19	3.45		9.00
4	Argentan — Ma, Je, non fériés: 5256 Alençon 5272/5461 Fresnay s/S. 5464/5275 Alençon	11.52	3.22		8.30		
4	Me, Ve, non fériés: 5256 Alençon 5272/5461 Ségrie 5464/5275	11.52	3.22		8.30		
4	Sa, non fériés: 5256 Alençon 5272/5461 Fresnay 5462/5275	10.56	3.22		7.34		
4	Lu, non fériés: 1264 Alençon 5272/5461 Ségrie 5464/5275	6.58		0.20	6.38		
4	Dim. et fêtes: 5256	3.28			3.28		
5	Alençon — sem. sf SVF: 30457 Pré-en-Pail 30456 Alençon 5252 Le Mans	10.40	2.56		7.44		11.20
5	SVF: 30457 Pré-en-P. 30456 Alençon 5252 Neuville 1273 Alençon	11.13	2.56		8.23		
6	Le Mans — semaine sf ILF: 5253 Alençon	4.14			4.14		

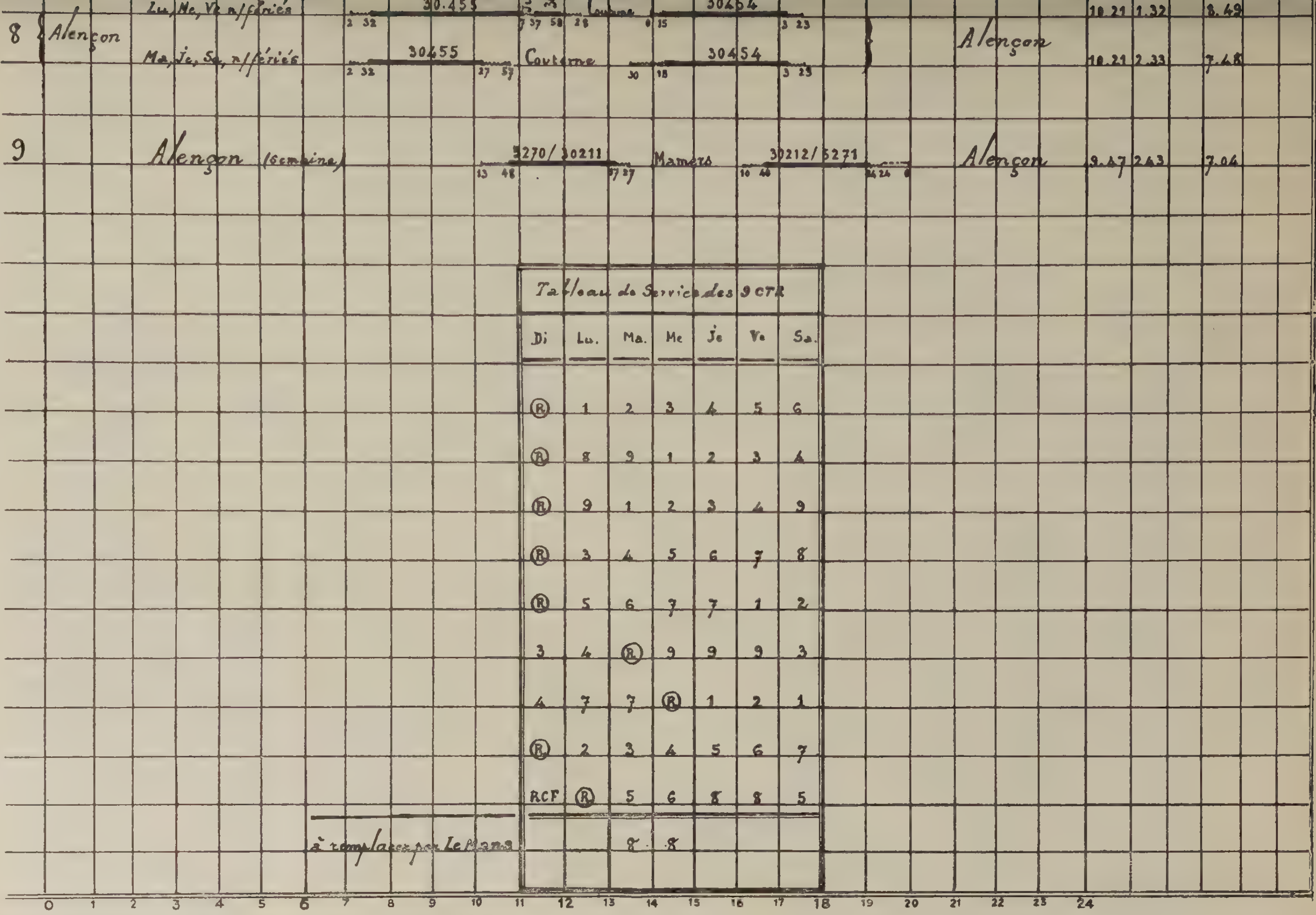


Fig. 1. — Roster of train staff on regular service.

LEGENDE = LEGEND.

Haut le pied = light runs. — Pause pour repas = time off for meals. — Opérations avant départ et à l'arrivée = operations before departure and on arrival. — Service de gare = service in the station. — Réserve à disposition = reserve. — Parcours à pied = journey by walk.

Each central control is managed by a Head Controller assisted by a certain number of operators who are permanent staff (Photo of the Chambery Central Control. Fig. 5).

To begin with the central control draws up every month a monthly programme showing the use to be made of the train staff :

— for the rostered staff, the service each employee is called upon to do every day is written down in advance;

— for the reserve staff, expected absences are written down in advance (rest periods, holidays, illness, absences on other duties) and the programme is completed as the month goes on.

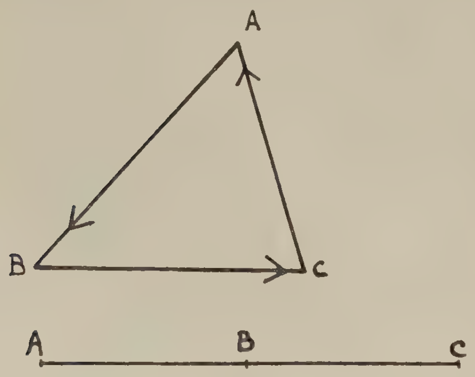


Fig. 2.

This monthly programme makes it possible to have a daily orders sheet on which the central control writes down :

— on the one hand, requirements, viz :

1) special or supplementary trains that need reserve train staff, showing the route over which such trains require staff and the time of departure and arrival;

2) replacements of train staff to be allowed for, showing the train on which they will leave, the departure station, the time at which they will leave and the time at which the corresponding service will begin;

— on the other hand, the spare labour available :

1) men available due to the suppression of regular trains which are normally accompanied, or light engine runs which the regulation of work has made it necessary to include in the rosters and which can be turned into service runs for working special trains or to replace rostered staff;

2) reserves available at each locality, showing for each man the hour at which he becomes available and the date at which his next rest period on the monthly staff programme is due to begin;

3) men taking rest periods in localities other than that to which they are attached, showing the hour at which they will again be available for duty.

The Permanent Operating Department staff of the region keep the central control closely informed regarding the running of special and supplementary trains or the suppression of regular trains; such information is given in principle 4 times daily, but can be altered or completed at more frequent intervals whenever necessary.

The stations advise the central control of the times at which all reserve train staff goes on and comes off duty.

In this way, the central control knows at all times what are the requirements and available resources, and is able to

Fig. 3. — The forty Operating Regions of the S. N. C. F. with their Central Control of train staff Offices.

utilise the men in the best possible way; for this purpose, the following order of priority has to be observed in dealing with the staff :

1) Use of train staff from other localities, either during the same working day or after the appropriate period of rest away from home.

2) Use of men provided for light running duty on the regular services.

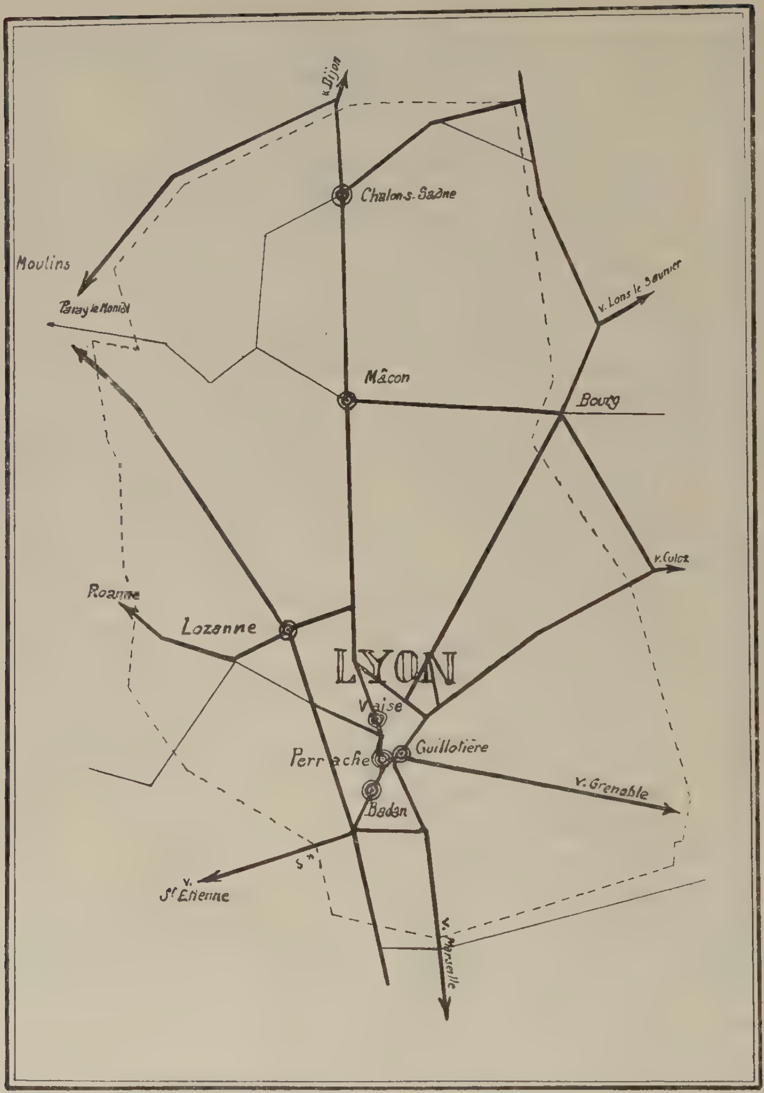


Fig. 4. — Lyons Region and its seven localities where the train staff reside, dependent from the Central Control.

3) Re-use of reserve staff which has already travelled with one or several trains within the limits laid down by the Labour Regulations.

4) Use of spare regular staff available owing to the suppression of certain trains on certain days of the week.

5) Use of fresh staff from the reserve.

The central control is authorised to modify the regular runs when service requirements make it necessary, and in particular, when such a modification will make it possible to reduce the total number of men used.

The programmes thus prepared for the use of train staff as well as the regular turns of duty may be more or less affected by delays to the trains or any incidents which occur in service; for this reason the central control is advised by the Regional control posts of all delays and incidents; this makes it possible for the central control to take whatever steps are necessary should there be any

Fig. 5. — Chambery Central Control with the permanent staff dealing with the control of special trains.

break in communications or likelihood of infringing the Labour Regulations.

The number of combinations which the Central Control can work out is endless, and a skilled employee soon learns how to make very substantial savings in staff whilst meeting all requests for days off put forward by the staff; the resources of the various localities of the Region are pooled and the central control is able to assure the service by taking men from localities where few have asked for time off in order to be able to grant days off to men in other localities. Cases have occurred where all the men from one particular locality having asked for the day off because of a local fête, the service has been carried out entirely and under completely satisfactory conditions from the economic point of view by men from adjoining localities. For example in 1955, for the Mid Lent Fête at La Rochelle, where there are 34 train staff employees, 22 of whon belong to the regular service, all the men were able to take a holiday or have their rest period the day of this fête.

Under these conditions, local controls merely act as an intermediary between the central control and the men themselves in order to advise each employee what his duties will be; they also advise the central control of all requests for time off put forward by the men, when they are not available owing to sickness and for other reasons; finally, they advise the central control the hour at which an employee is due to go off duty, so that the central control knows when they will be available again according to the Labour regulations that have to be observed.

In most cases, it is no longer necessary to have specially trained staff in the local controls and such staff are now redundant; the duties of the local controls are then combined with that of some other station organisation (Secretariat for example) or even with another department (Depot). Thus out of the 307 local controls in existence in 1950 on the S. N. C. F., there now remains only 140, i. e. about 45 %.

This results in savings in staff which very largely makes up for the creation of the central controls, but the chief saving is due to the better user of the train staff; it has been calculated that on one region of the S. N. C. F. where the train staff now numbers 2 000, 400 men have been dispensed with over the last four years by the progressive extension to the whole of the districts of this Region of the new central control system.

The preliminary estimate of the saving to be expected from the generalisation of the central control system over the whole of the S. N. C. F. is about 2 000 men.

[625 .13 (44)]

Reconstruction of the bridge across the Saone at Macon,

by A. LAZARD,

Ingénieur en Chef, Chef de la Division des Ouvrages d'art de la Société Nationale des Chemins de fer français.

(*Revue Générale des Chemins de fer*, December 1954.)

The double line from Macon to Amberieu crossed the Saone 2 km below Macon station by a bridge which was totally wrecked in 1944 and has now been rebuilt.

The piers, 4 in number, were each formed by three cast iron pillars filled with concrete and braced with struts. Each pillar supported a strut on which the corresponding main girder rested.

Fig. 1. — The old bridge that was destroyed.

The old structure.

This was built in 1856. The deck was formed by three main iron girders with continuous webs, 3.508 m (10.455 ft.) high, but certain parts of the upper members were of cast iron. The tracks resting on timber longitudinals were supported by a classic combination of short bridge pieces and iron longitudinals.

The spans measured about 39 m (127.95 ft.) between centres (two 39.45 m [129.43 ft.] and three 38.84 m [127.42 ft.]). The total length of the structure amounted to 195.5 m (641.40 ft.).

The bridge was destroyed in 1944 by the retreating German army, who cut the deck into several sections and blew up the foundations (fig. 1).

Part of the deck might no doubt have

been repaired, but the Saone suffered a serious flood during the winter of 1944-45 which caused the sections of pillars to be overturned and sunk. In the end (fig. 2) only two pillars remained standing and these were overturned and damaged, and nearly all the decking blocked the bed of the river. It became necessary to clear the bed without delay and prepare for total reconstruction of the bridge. The work of clearing was carried out by the navigation control authority.

it calls for enlargement of the piers and foundations, and in general for superelevation of the rails on account of the total thickness measured from the head of the rail to the flanges of the small road bearers. In this particular case, the superelevation of the track was practicable but was made difficult by the navigation's requirements, which called for an air space of 6 m (19.68 ft.) above the highest navigable waters through two navigable channels of at least 24 m

Fig. 2. — The old bridge after the Saone had flooded.

(78.74 ft.) width, in place of the 5.18 m (17 ft.) of the original structure. The foundations of the pillars, which were examined by a diver, having been found useless, with the exception of the lower part of one, and the adjacent local service to the Saône-et-Loire calling for the widening of Departmental Road 51 which follows the left bank in passing under the work which runs alongside the abutment at Amberieu, forced them to extend the

New structure.

It was at once decided to build a modern type of bridge, very different from the old pattern, which would comprise multiple metal girders supporting tracks carried on a new reinforced concrete decking to support the ballast for the necessary sleepers. This type of bridge has great advantages for the work of track maintenance. On the other hand.

length of the decking, and they were thus obliged to adopt a continuous structure 199.90 m (656.14 ft.) long in seven spans of 27.4, 30, 30, 30, 26.5, 26.5 and 28.5 m with five new pillars, one pillar and the abutment at the Macon side partly utilised again, and a new abutment on the Amberieu side.

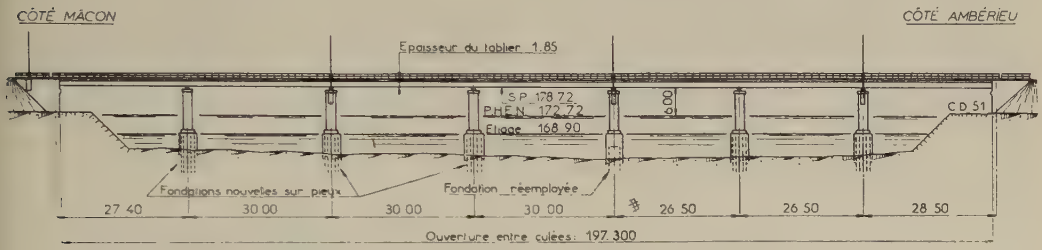
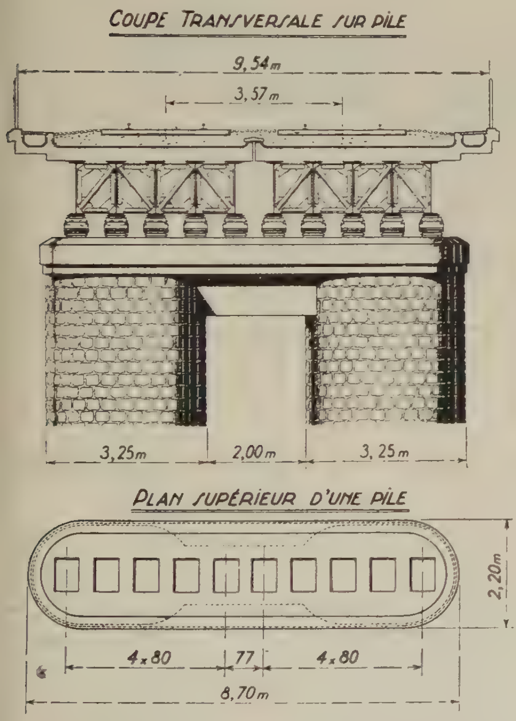


Fig. 3. — Elevation of the new bridge.

Explanation of French terms:

Côté Macon = Macon side. — Côté Ambérieu = Ambérieu side. — Epaisseur du tablier = thickness of support: 1.85. — Fondations nouvelles sur pieux = new foundations on piles. — Fondation réemployée = old foundation re-used.

The beam supporting the decking was made polygonal in order to reduce the raising of the tracks at the embankments; this beam was raised by 0.82 m (2.69 ft.) at the two navigable channels, while the rail itself is raised to a maximum height of 1.17 m (3.33 ft.). The maximum span (30 m [98.42 ft.]) was fixed in view of the adoption of light Grey metal beams



Coupe longitudinale sur pile.

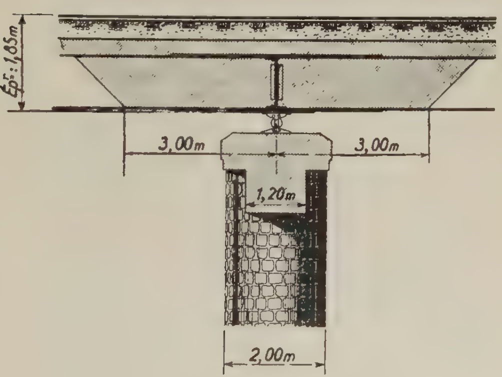


Fig. 4. — Sections in line with the piles.

Explanation of French terms:

Coupe transversale sur pile = cross section of pile. — Plan supérieur d'une pile = upper plane of pile. Coupe longitudinale sur pile = longitudinal section of pile.

of 1 m (3.28 ft.) which could be supplied by the S. N. C. F.

The two supports, one for each track, rest on trimmers connecting the two shafts (see fig. 4) of each pillar.

Each support, of ferro-concrete, much used on the latest railway bridges of the S. N. C. F., consists of five short beams of Grey HN 1 m high, spaced 0.8 m (2.62 ft.) apart and stiffened by plates welded to the flanges of the short beams and anchored to a concrete support, at least 20 cm (diam. 7 7/8″) thick, to carry the ballast and the track.

This support is prolonged at the ends which overhang the ends of the last short beam to form a separate duct for carrying signal cables and ultimately various other conductors.

In general, in the calculations for bridges of this type the strength of the decking is not taken into account, although it is known that this actually takes part in the general stressing of the structure, and to a certain extent eases the stressing of the short beams. However, in this case, allowance was made for the effective participation of the decking. The work being continuous it was considered advisable to cover completely one portion of each pillar over a length of 3 m (9.81 ft.) with reinforced concrete in order to stiffen them.

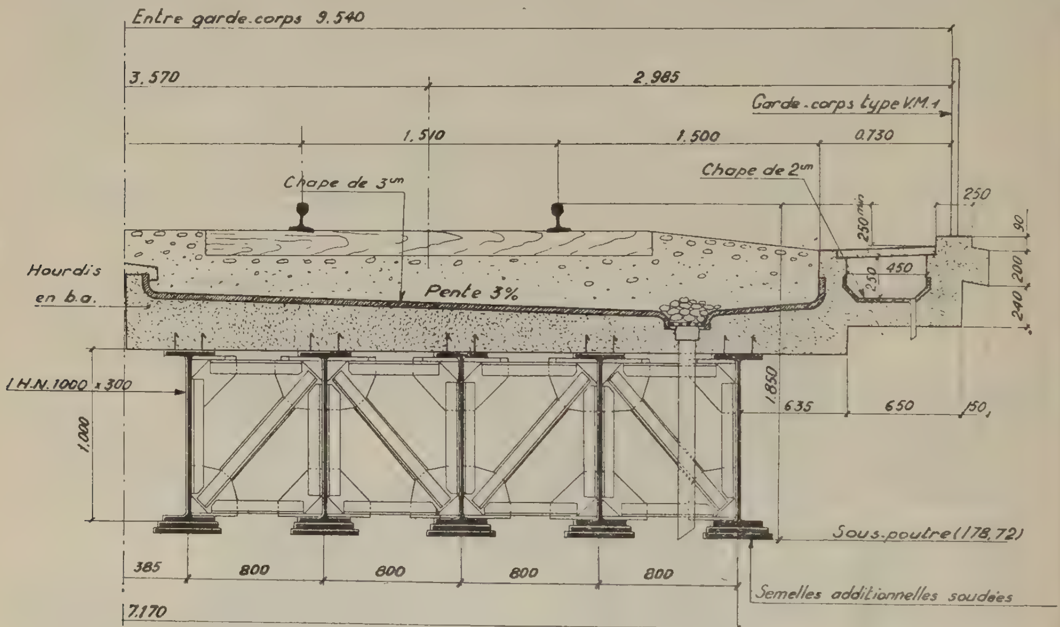


Fig. 5. — Cross section of one track.

The light girder components which were available from the S. N. C. F. ranged from 5 m to 29 m (16.40 ft. to 95.14 ft.) in length. After sorting these out carefully, the parts which were to be made up into beams were joined up, using *rivetted* joints, placed in positions where the bending moments would be very slight. The beams are braced approximately every 4 m (13.12 ft.) by a short brace, rivetted on in the vertical plane,

except where they are close to the pillars, where the bracing is effected by the concrete coverings 6 m (19.68 ft.) long already referred to.

These beams are set on the masonry of the abutments and pillars by mobile supports the rollers of which are of hardened steel to economise space and weight. Fixed supports were anchored to the new Amberieu abutment, designed to take up the stress due to braking. Hence the whole bridge expands away from the Amberieu abutment, as against other more usual methods where the fixed point is placed at the centre of the structure.

Details of the structure.

a) *Foundations on metal piles.*

As already stated, the work comprises 6 piles in the river, 5 of which are new. It had been decided to test under water various types of constructing at that time unknown in France, but owing to various delays interest flagged, and in the end the problem was only examined seriously

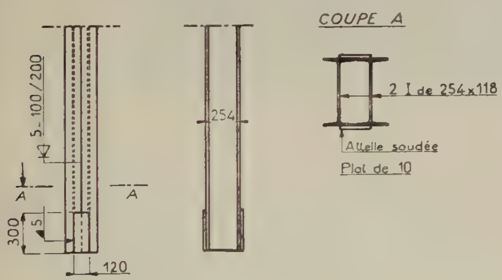


Fig. 6. — Metal pile.

in respect of deep foundations with metal piles, which were subsequently served with wet concrete sheltered by a fence of metal sheet piling driven to a fixed depth and suitably benched on the face of the slope.

Metal piles have been in use for a long time and extensively in the U. S. A. and Canada. According to inspections that were made when the foundations were rebuilt, the loss by wear from corrosion appears to be very slight, and it does not appear that in these parts of North America this practice has resulted in miscalculations. The trial at Macon is, so far as we know, the first of its kind in France.

The piles were made of two beams I of 254 × 118, 18 m (59 ft.) long, coupled in pairs by welding (fig. 6). They could carry a load of at least 62 tons. They are certainly less costly than classic piles of reinforced concrete and are more easily driven. The operation was perfectly successful as we obliged the contractor to take special precautions in the welding and calculation of the couplings. We consider these precautions indispensable. A partial failure recently observed at a small reconstruction job would seem to have been due to the absence of such precautions.

Pouring the concrete for coating the piles within the cover sheeting did not give rise to any remarks.

On this concrete there are two posts made up of ovoid flints covered externally with large pebbles embedded horizontally which served as linings. As we have stated, the said posts are joined at their upper parts by a strong trimmer of reinforced concrete on which the structure rests.

Of the old foundations now being used again, there has been preserved the bases of the three cast iron columns filled with concrete, lightly spread below the bed of the river.

In fact, the three former columns were found, several years after the river bed had been cleared, to have been practically cut back to the river bed. It could be assumed that they were in good conditions from a line about 1 m (3.28 ft.) below the said level.

It was therefore decided to finish them with a strong trimmer in reinforced concrete and to mount on this trimmer a pillar built up of two posts exactly similar to those of the other pillars.

b) *Placing the beams by using a special lifting wagon.*

The parts of these beams, which varied in length from 25 to 30 m (82 to 98 ft.) had been carried forward in pairs by means of the special conveyor wagon (fig. 7).

This wagon, built at the end of the war by the Maison Moisant-Laurent-Savey, consists of an enormous stayed beam 40 m (131 ft.) long, mounted on a truck with 6 axles forming a horizontal jib overhanging the truck by 15 m (49 ft.) and capable of carrying at this extension loads of 25 to 32 tons. The whole outfit includes several flat trucks which can be pulled or pushed by a locomotive.

The beams having been brought up on a branch line some distance away from the point of use, the wagon approaches and raises the jibs. The train is shunted towards the opening and the jibs are lowered to the requisite level. One of their extremities is engaged with the joint-cover of the jib already in position, while they rest on one of the pillars, some metres away from their other extremity. When the beams are properly balanced, they are uncoupled from the special wagon which can be sent back to its siding to pick up another pair of beams.

At Macon, it took about one hour to deal with the placing of a couple of beams 33 m (108 ft.) long.

This special wagon is very much used by the S. N. C. F. for setting new bridges and for removing temporary work. It takes 3 days to erect into working order and 2 days to dismantle. The S. N. C. F. are ready to loan it to undertakings who wish to use it. It is a most useful machine. The makers of the equipment are at the moment building another such machine of greater scope and power, with slight differences in the specification.

Fig. 7. — Special conveyor truck.

c) *Using « probeton » in the concrete mixture for the supporting beam.*

The concrete for the support was mixed in two distinct phases. The first

was for the coating by 6 m (19.68 ft.) of concrete about each support on a pillar, the second, the beam deck supporting the ballast properly speaking.

We requested the contractors to make a trial on this second phase of an auxiliary which is intended to improve certain characteristic qualities. This is « Probeton » sold by the Socopa Co. It is a residual obtained in the manufacture of a paste used for making paper: chemically a lignisulphite of calcium [1].

As far as we know « Probeton » is a French product. It acts above all, at 0.5 % of the weight of cement, as a defloculant of the cement. Due to its tenso-active properties, it opposes the formation of small coagulated bodies of cement with the result that the cement is brought into much closer contact with the water, an excess of which is no longer indispensable; theoretically speaking one might be satisfied with adding just enough water to combine chemically with the cement. In practice the use of « Probeton » permits reducing the water added by 10 to 15 %. Under these conditions according to Feret's law, the resistance of the concrete to crushing is slightly increased in the proportion of $\frac{C}{E}$ (cement over water). The concrete as it leaves the mixer appears to be rougher than ordinary concrete, but once it is vibrated in the mould, it becomes very fluid and flows freely round the reinforcements.

Moreover, it hardens fairly quickly and it is not necessary to keep up the vibration for so long.

Owing to the reduced quantity of excess water, one might think that the shrinkage of concrete treated with Probeton — due to a considerable degree, according to commonly accepted opinion, to evaporation of water which had not entered into chemical combination — would be less. This is one of the main reasons why we were interested in the product, since the shrinkage of concrete appeared to us as one of the essential causes of the fissuration which is noted on all existing concrete works. In fact, it does not look as if the shrinkage of the concrete will be influenced to any great extent by addition of the product. On this particular point, our experiment failed in its object. On the other hand, we have noted — and this was not mentioned amongst the advantages of the product — an *enormous increase* in the resistance to tractive stresses, or more exactly to the *resistance to bending* shown by the prismatic test-pieces broken by the uninterrupted bending stress to which they were subjected. This increase is very marked, and at times reaches 50 %. This increase in tractive resistance should delay the appearance of the fissures due to tractive stresses, and perhaps those caused by shrinkage. In effect, there is a sort of competition in speed in freshly mixed concrete between shrinkage which gives rise to tractive stresses in the specimens, and which increases slowly as time goes on, and the increase, slow at first, of the tractive resistance. In general, the harmful effects of shrinkage are seen before the concrete may have sufficient resistance for the tractive effort, and it is in this way that the first fissures due to shrinkage are to be seen.

Other fissures due to shrinkage may arise later.

In fact, shrinkage continues to be noticeable over several years and the tractive stresses due to shrinkage increase slowly; on the other hand, the tractive resistance, following a slow period of disconnection, then reaches a value which for a time prevents the appearance of new fissures, but which quickly becomes stabilized. It

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[1] This material is the basis of numerous products sold as plastifiers for concrete; other products are usually incorporated intended to give other qualities, but these make the product expensive, and they are usually produced by foreign firms and their value is often doubtful.

is possible that after a delay of between 18 months to 2 years, the traction stresses due to shrinkage may again exceed the tractive resistance. In the meantime the concrete, having moreover aged and hardened, will be less inclined to lend itself to plastic deformation and becomes more fragile.

Be that as it may in respect to the arguments put forward above, the increase in tractive resistance which results after the first days of the addition of Probeton would appear apt to diminish or even suppress the cracks due to shrinkage. The tests made on the Macon Bridge at the same time as those on other works, later followed up at numerous works, will show whether we have found an effective answer to the problem of fissuration in concrete work. So far, however, the tests have not been conclusive. The trials must be continued.

From every point of view, it is definitely interesting to be able to obtain concretes having increased tractive resistance, since the fissures in traction work under load will be held back and in the case of prestressed concrete, it will be possible to make allowance in the calculations for a certain resistance to traction.

In this connection, we are glad to see that one of the biggest firms supplying ferro-concrete in France and an excellent local undertaking in the West of France, who used Probeton on our recommendation, have systematically generalized the use of this material in their works.

We ourselves are trying hard to persuade our contractors to use this addition; we are in general well seen, and so far have only met one firm who object to taking up this product.

Nevertheless, it is necessary to take certain precautions : slightly reduced vibration, and oiling or greasing of the forms made of soft wood. Finally, it is necessary that the men in charge of the concrete mixers should get their hands in with a few days practice. As we have stated, since the concrete requires less water, it leaves the mixer richer; it is therefore necessary for the men to accustom themselves to this new feature. Moreover the strictly minimum quantity must be ascertained experimentally on the job, by systematic trials, by trial and error, by reducing little by little the amount of water added. If there is no danger that the mixer is likely to supply a very great excess of water, as in that case the concrete would look like soup, we have to guard against too much water which will reduce the strength, or on the other hand too little, which would not allow of the complete hydration of the cement.

The considerable increase in traction resistance obtained in the regular bending test, the increased adhesion of the reinforcement shown in some laboratory tests, and some cases of sticking on soft wood moulds which were not greased, lead us to think that concrete treated in this way may show better adhesion to stone. In order to clear up this question, we asked Professor Capdecomme of the Faculty of Science in Toulouse and his assistant Dr. Farran, who have recently perfected a process for measuring the adhesion between cement pastes and stones, to undertake some measurements with ordinary concretes and those made up of the same constituents with the addition of Probeton.

This study has now just been started. Let us hope that it will throw some light on these still somewhat obscure phenomena.

In conclusion let us add that the Probeton may be introduced with the water for mixing; this would evidently be the best way, but it is not utilised in practice, since the majority of the concrete mixers at the French works do not possess « measuring » containers worthy of the name. In fact the dose of Probeton is spread over the cement before it is introduced to the concrete mixer. It is therefore important to see that the

Casting dates	Pressures on cubes in kg/cm^2			Simrup (1) tensions in kg/cm^2			References and Remarks
	7 d.	28 d.	90 d.	7 d.	28 d.	90 d.	
							1st Support V-1
3-11-1953	365	468	583	57^5	58^6	67^3	2nd Span. Vallette composition.
16-11-1953	408	515	568	54^9	61^5	66	3rd Span. Vallette composition.
30-11-1953	334	533	546	48	54^4	56^8	5th Span. Vallette composition.
15-12-1953	371	453	523	55^1	60^9	62^8	7th Span. Vallette composition.
							2nd Support V-2
17-2-1954	330	490	525	46^5	55^4	69	1st & 2nd Spans. Vallette Comp.
5-3-1954	369	488	496	36	58	62	Spans 3/4. Vallette cappings
12-3-1954	356	458	464	46^8	62^5	66^8	Spans 4/5. Valette cappings
27-3-1954	302	443	513	61^3	61^8	61	6th Span. Vallette composition.
30-3-1954	386	496	568	45^2	67^2	68	7th Span. Vallette composition.
	for comparison concrete without probeton						
16-3-1954	361	445	450	42^6	50^1	55	Gusset pier 5. Vallette compos.

(1) Formula $\dfrac{6M}{b^3}$ d = days.

Fig. 8. — Results of tests on concrete.

mixing in the concrete mixer is carefully looked after.

The table in figure 8 gives some results of tests on the resistance to crushing and to bending of the concrete used for the Macon bridge.

d) *Execution of the work.*

The work has suffered several changes of fortune, since it has been held up on several occasions by questions of cost.

The *civil engineering* work was entrusted jointly to the Entreprises Bollard of Paris and Pierre & Pasquet of Paris.

In fact, it was the last-mentioned undertaking — quite a new firm — who alone took charge of the work to our satisfaction.

The equipment of the workings consisted essentially of :

— an elevated cableway crane, with adjustable jibs, which can carry all loads, starting from the banks;

— pile-drivers bell steam-driven, mounted on a floating pontoon;

— a Derrick pontoon;

— concrete mixers and other usual appliances.

The order of operations on each pile was as follows :

— dredging out the bottom of the river to a depth of 1 m (3.28 ft.) at the position where the foundation was to be built, in order to remove the mud and to ensure that the concrete coating for the piles secures an effective support on the sand and gravel at the bottom of the river;

— driving the piles with the pile driver;

— driving the sheet piles with a Derrick pontoon, fitted with a vibrator;

— pouring the concrete, under water, for encasing the piles, the concrete being mixed on the bank and transported by the elevated cableway crane;

— construction of the masonry for the posts and upper trimmers of reinforced concrete for the piers;

in a bed of clay in order to permit of draining, which was moreover relatively easy.

The former pillars were disconnected over about 1.50 m (4.91 ft.) below the level of the bottom of the bed and all the disconnected parts were carefully removed.

The new trimmer in armoured concrete

Fig. 9. — The completed bridge.

— cutting off the sheet piling at low water level;

— casting the inclined plane joining the heads of the sheeting piles with posts for the piers, in order to prevent the flood water from endangering the barges.

In the procedure for reutilising the old pier foundations which had been preserved, operations were slightly different.

An enclosure of sheet piles was built

was then built; it caps and encloses the three columns so as to give them the best form of wind bracing.

On principle the new trimmer could be recovered, but its recovery would cost as much as cutting off the sheet piling level with the bottom of the river.

It was this part that was retained because it was less risky and in addition the making of a bank of concrete to form a block against the trimmer and

against the curtain of sheet piling at the level of the bottom of the river, would at the same time prevent any erosion and would considerably increase the safety of this somewhat heterogeneous foundation.

Taking it all in all, the pillars and foundations called for the laying of 3 000 m^3 (3 924 cubic yards) of concrete. The two supports for one track required 900 tons of metal and 850 m^3 (1 112 cubic yards) of concrete.

The preparation and erection of the supports was entrusted to the Seibert works at Sarrebruck.

The spans will be provided with light gangways for inspection work, which have already been put in hand at the S. N. C. F. shops at Nevers-Machines.

[656 .212 .5 (73)]

Electronic « Brain » classifies cars.

Houston's new electronic yard, to be completed this year, heralds future SP developments looking toward a second century of efficient service.

(*Modern Railroads*, August, 1955).

Englewood Yard, Houston, Tex. is system's newest and most efficient yard. Costing $ 7 million, it can put a car over the crest every 12 sec. An electronic brain and a radar device control car movements.

In the gloom of night, a heavily loaded steel box car rolls down the « hump » in the Southern Pacific's new Englewood Yard at Houston, Tex. It is untouched by human hand.

Suddenly its ghostly trip is slowed. An electronic « brain » that « remembers » and « thinks » gave the directive.

This device recorded the weight of the car, its speed (measured by radar), and the distance it must travel to its place in a string of Chicago-bound cars on a sorting, or classification, track below. The « brain » computed the speed at which the car must arrive to avoid a damaging slam into the car ahead. Automatic

« retarders » then reached in from the sides of the rails, squeezed the car wheels, and slowed them down.

Ahead, the unseen hands of the electronic brain throw switches which automatically guide the car into its destination machine that doesn't make human mistakes. The era of « electronic railroading » has taken another long step forward. SP's $7 million Houston yard — when it's finished in December — will be capable of putting a car over the

Crest control tower is one of three from which yard operations are directed. Yardmaster's tower is centralized in the yard bowl. Retarder tower enables yardman to monitor radar and routing controls.

track. The big freight car curves in, eases gently up to the car ahead.

This use of radar to measure speed, along with a mechanical « brain » to weigh that factor in relation to weight, has turned another chore over to a hump every 12 seconds, around the clock, aided by the science of electronics.

That kind of railroading is typical of the restless, driving force that is the Southern Pacific, whose steel rails bind together a « golden empire » extending

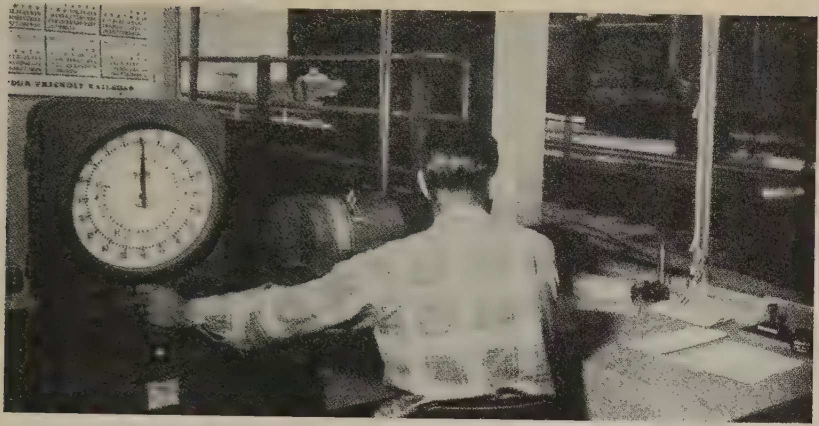
At console atop the crest tower, classification operations are directed. The yardmaster's and retarder towers have similar consoles.

From this push button panel on the second floor of the crest tower, an SP engine foreman sets up car routings into classification tracks.

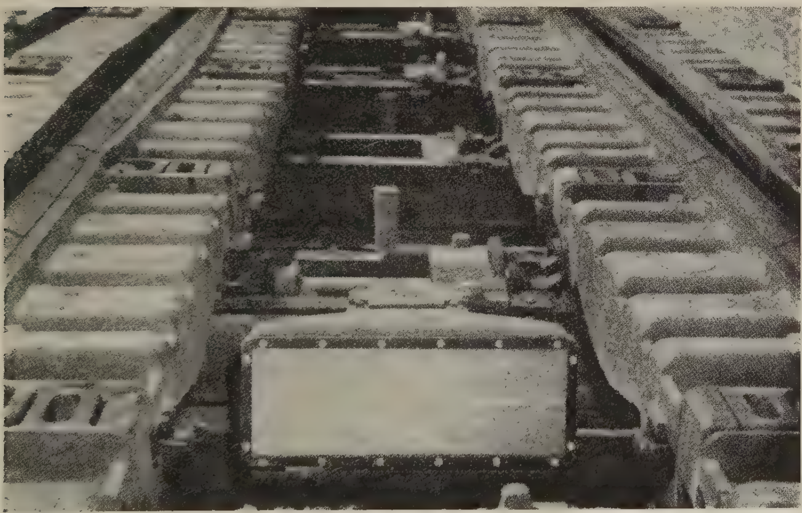
from Portland, Ore. through the West and Southwest to New Orleans, La.

Englewood, scene of this electronic classification, is the key yard on SP's busy Sunset Route. It blocks trains for eight sub-divisions of SP's Texas and Louisiana lines which radiate in all directions from this industrious city. In addition, it feeds seven nearby subyards and numerous industrial sidings.

Classification, thus, is a big job at Englewood. Virtually all trains moving into



Freight cars are weighed electronically as they roll down initial three percent grade. Equipment makes a permanent record of weights.



A radar antenna in each of 18 braking units measures the speed of approaching cars and sets retarders to slow each car to right speed.

this center must be reclassified. The only exceptions are California-New Orleans blocks, St. Louis perishable blocks, and two westbound blocks which consolidate with the Motor Special at San Antonio, the first Division Terminal west of Houston.

Behind the modernization of Englewood went months of careful planning. Before a spade of dirt was turned, the railroad sent out a scouting party to look at other major yards.

G. W. Kelly, Superintendent, and several of the railroad's engineers were charged with the task of finding the most efficient

yard in design and operation and then creating a better one.

« Obviously a gravity yard was required to handle our volume efficiently », explained Mr. Kelly. « But since the efficiency of a gravity yard depends largely on continuous operation of the hump, we recommended the pull-back, saddle-type yard. »

Following this plan, a 48-track classification yard with an ultimate capacity of 64 tracks was built. It is flanked by two receiving yards, one on each side; hence, the name « saddle-type ».

To feed the hump, two « pull-back » leads, one from each of the receiving yards, extend from the receiving yards to points well behind the hump. Using one or the other of these « pull-back » tracks, each train is pulled around the hump. Thus, while one switcher is pulling back a train, another is pushing a string over the hump.

With the saddle-type plan, hump traffic is free from congestion caused by other traffic such as light locomotives or inbound trains.

To insure smooth operation with a minimum of human errors, automatic switching and automatically controlled retarders are used. The yard's automation equipment was worked out in cooperation with the General Railway Signal Company.

Operation of the automatic retarders permits freight cars with varying loads to roll down the hump to any classification track at safe coupling speeds. Adverse weather conditions with poor visibility which would bring conventional push-button yards to a standstill have no effect on Englewood operations. Piercing radar beams « pick up » the cars as they approach the retarders and set the electrical control circuits for the proper amount of retardation.

An electronic brain was developed to work with the radar speed control. This development literally brought gravity switching into the realm of science fiction. Here the wizard hands of electricity do a giant's share of the work. The tower operator has only to press a button corresponding to the track on which he wants a given car spotted. The automatic switching system and the electronic brain do the rest.

Thus, modern science is helping Southern Pacific increase its capacity to move shipments and provide better service to its shippers.

Control of the yard is centered in a three-story tower. On the second floor, the crest conductor routes cars to the various classification tracks by simply pushing a routing button. The automatic switching machine operates the necessary switches to place each car or cut of cars into the desired classification track. The crest conductor can punch as many as four routings at one time. The machine will remember these and will choose the desired route for each car as it rolls down the hump.

From the third floor of this crest control building, the yardmaster oversees the entire operation and issues the necessary instructions to keep yard operations moving smoothly.

Down on the first floor is the electronically operated automatic track scale. This equipment, manufactured by Cox & Stevens Aircraft Division of Revere Corporation of America, weighs the cars as they roll down the initial three percent slope of the hump. The scale is 92 ft long and is supported on eight load cells.

The entire crest control building and the 50-ft bowl tower are air-conditioned. The latter tower, located at the emptying end of the classification tracks, is the nerve center of the yard. It is served by a two-man elevator.

Once a car starts rolling, the electronic brain takes over, guiding and controlling each car. Should the crest conductor make a routing mistake, he can correct this by operating a correction button.

« The so-called electronic brain, how-

ever, does more than remember », explains Kelly, « It checks on seven different factors regarding the car, its characteristics, and the distance to which it is rolling. »

First of these factors is car weight. works against a heavy spring so that the amount the treadle is depressed depends upon the car's weight. Electrical contacts report back to the « brain » whether the car is light, medium, or heavy. This

Unconventional in its approach, this message explains a technical advance to the public. « Railroading by Radar. »

This is important, because heavy cars have different rolling characteristics from light cars. Also greater braking pressure can be safely applied to a heavy car. Hence, a weight detecting device is located immediately ahead of each retarder. This consists of a treadle which simplified classification is sufficient for the guidance of the retarder.

The second factor which the brain must know in order to control the retarders is how fast the cars are rolling. An automatic radar control accomplishes this instantaneously. At the end of each

retarder, a radar antenna unit focuses a searchlight-like beam of ultra-high frequency waves toward the approach end of the retarder. As a car enters the retarder, the beam strikes the car and some of the waves are reflected from the car into the antenna unit, technically known as in interferometer. Because the car is moving, the frequency of the reflected wave will be slightly different from the original frequency. The difference between the reflected radar wave and the original wave constitutes a measure of the speed of the car. The electronic brain interprets this and instructs the retarder mechanism to act so as to release the car at the optimum speed. A radar control of this type gives an instantaneous and continuous indication. Furthermore, the radar operates effectively through fog or the darkest night. A total of 18 radar antennas or windows are employed. One controls each of the six sections of the master retarder, and two are used for each of the six two-section group retarders. Each 99-ft group retarder pair serves eight tracks.

Optimum release speed is the toughest problem.

Toughest problem for the electronic « brain » is the determination of the optimum release speed. At this point, the electronic computer section comes into action. It must consider two factors : the rollability of the car and the track resistance which the car will encounter on the route selected. This latter is an important factor, for just as no two cars roll alike, no two tracks offer the same resistance. Some are longer and have greater curvature than others. The electronic computer also watches for long « cuts » involving several coupled cars bound for the same classification track. These have different rolling characteristics from single cars.

The electronic computer determines rollability by checking the gain of speed for each car between the time it is released from the hump retarder and the time it enters the group retarder. At the same time, the automatic switching system tells the computer what track the car is bound for. The computer feeds this information into the « brain » which determines the speed at which the car is to be released from the group retarder. With the continuous control possible with radar, the electronic brain is in touch with the car as long as it is in the group retarder. Thus as the car slows down in the retarder to a speed near the correct value, the « brain » tells the retarder to ease off a bit. Then when radar tells the « brain » that the car is running at the correct speed, it releases the car which rolls into the yard at a safe coupling speed.

Several factors, however, remain under the control of the retarder operator located in the power and retarder equipment control tower. If necessary, he operates the weather control which changes the car relase speeds as may be required to meet exceptional weather conditions or other factors affecting the rollability of cars. Also he operates a control which tells the retarder mechanism whether a car must roll a long way or a short way after it leaves the group retarder.

When necessary, the retarder operator superimposes manual control over the automatic car braking equipment and also over the automatic switching equipment.

Traffic pattern determined site of hump.

Because of the Englewood traffic pattern, it was necessary to locate the hump east of the classification tracks. The exact location for the crest worked out directly over the main tracks of the Houston Belt & Terminal Railway. This necessitated a 27-ft high crest, resulting in a 5.9 % grade. Such a grade requires more than normal retardation.

« At least, our cars break away fast.

If they won't roll, they'll slide », points out Kelly.

Additional problems resulted from a city requirement to allow ample clearance for two double lanes of a superhighway. To meet all these conditions, the main crest is located on a concrete and steel ballasted deck structure. This rests on spiral welded pipe piles filled with concrete. Lap switches are used to shorten the distance between the apex of the hump and the clearance points to the group retarders. This insures fast clearance of cars and speeds up the entire humping operation.

As the layout of this 4 ½-mile yard progressed, it became apparent that the crest or master retarder would fall in part upon a bridge across Hunting Bayou. This posed certain design problems in order to insure that the bridge could resist he braking action.

The yard has three tower structures and 24 miscellaneous buildings.

In addition to the crest control tower, the power and retarder equipment building, the yard includes general yard office, interlocking control tower, inspection station, and five large locker rooms. Key buildings are air conditioned.

Ample communication facilities have been provided. There are 38 paging speakers and 238 talk-back speakers in the yards, manufactured and supplied by Electronic Communications Equipment Company. To serve these, 31 miles of underground communication cables criss-cross the area.

The communications system also includes a bank of six Teletype machines, a PAX dial telephone system, Ampex Electric high-fidelity recording equipment, and a full complement of PBX telephones.

« At entrances to the receiving tracks, we have car checkers who read off the initials and numbers of each car in the train as it passes the car checker station », explains Kelly. « This information is recorded on an automatic tape recorder system in the General Yard office which is located near the crest. From this information and from other information as to consist of trains, already in the yard office, switch lists for each train are prepared. »

Records for all trains and cars entering or leaving the yard are prepared on a complete business machine punch card system (see special article for details).

In addition to electronic communication facilities, a pneumatic tube system of 18 000 ft of 6-in. tube and 6 000 ft of 3-in. carries waybills and messages between key points in the yard.

All switchers working in the yard are equipped with two-way radio, providing open channel communication between locomotives and supervisory personnel.

Plans are being drawn for a closed-circuit television system to scan certain portions of the yard that are not clearly visible from the towers.

Block signals and interlocking systems at key points.

Block signaling and interlocking systems have been provided for key points and trackage. Under the interlocking systems, east bound entering switches are all power-operated and are controlled by a tower operator, having a clear view of the complex western entrance to the yard. All receiving tracks are equipped with signal track circuits with track occupancy panels in the interlocking and crest towers to indicate clear tracks.

On a track-side panel, the yardmaster will flash the track number on which he wants west bound trains to enter the receiving yard.

The yard also has a ground level inspection station. It is positioned so that eye-level of the car inspector is at the top of the rail. There also is a high-level station at which the tops of the cars may be seen.

The longest yard track at Englewood now holds 132 cars in the clear. Capacity of the classification tracks will be 2 975 cars; on receiving and departure tracks, 3 015 cars; on repair and shop tracks, 505 cars; and on miscellaneous purpose tracks, 110 cars. Total capacity is 6 605 cars.

With the yard partially completed and only 22 classification tracks in service, the railroad has put 2 641 cars over the hump in a 24-hour period. Over 300 cars were weighed on the automatic-electronic scale in this operation. Estimated capacity for full service is 3 500 cars as a regular operating level. The road expects to be able to reach a peak of 4 000 to 4 200 cars in a three-shift operation, should this be necessary.

Average speed of the cars moving up the crest will be maintained at from 2.5 to 3 mph. At this rate, a car will scoot down the crest every 12 to 15 seconds.

Even before completion, the new system of yard automation has proved itself — in terms of reliability, flexibility, and more efficient railroading. This development is a powerful new tool which the railroad is using to insure faster classification with increased safety and reduced damage to merchandise. The better blocking of trains aids rail operations far beyond the confines of the SP.

Developments of this kind stand as proof that the Southern Pacific System is ready at all times to meet the transportation challenge in its Western Empire.

[621 .431 .72 & 625 .28]

Rubber components for suspension systems.

A review of certain applications to springs, pivot and bolster equipment for bogie locomotives and railcars.

(*Diesel Railway Traction*, November, 1955).

Rubber bonded to metal is now used to a considerable extent for the suspension of Diesel locomotives and railcars, sometimes in entirely novel forms in which steel is almost eliminated, and in other cases where the rubber is used for certain details, leaving, for example, the axlebox springs of the usual laminated type. Apart from its elastic properties in springing, rubber has considerable noise-absorbing capacity, and this, as well as its spring characteristics, is being apreciated more and more by railways and builders.

Being a new material and a new medium as far as general railway rolling-stock practice is concerned, other than for auxiliary and drawbar springs, development has been in the hands of specialist companies, not only for the detail design of the components but also in the application to rolling-stock and motive power, and in the effect on the vehicle as a whole. Certain differences in practice can be discerned between the work of one manufacturer and another, and the details discussed hereafter are based on Metalastik products.

Modern practice in the design of rubber bonded to metals allows the introduction of such components into railcar and locomotive suspension systems in four distinct stages, viz. :

a) replacement of metal bearings subject to wear and static friction by rubber bearings, which accommodate the relative movement by elastic distortion. A typical example is the Spherilastik bush for pivotal movement, and plate-type mountings between the bolster and the cross stretchers of a bogie frame to eliminate sliding. A swing bolster modified in this way is shown diagramatically in figure 1;

b) the use of rubber instead of metal in springs, replacing the laminated, helical and torsion-bar types often by units of similar shape with no significant change in mechanical design. The advantages claimed for rubber used in this way are variation of stiffness with loading, reduction of noise, and, in some cases, saving in space and weight, or elimination of wear. If compression-type rubber springs, whether bonded or unbonded, replace the helical bolster springs, then the scheme shown in figure 1 is modified to that in figure 2. Rubber is used to provide both the flexibility for spring movements and

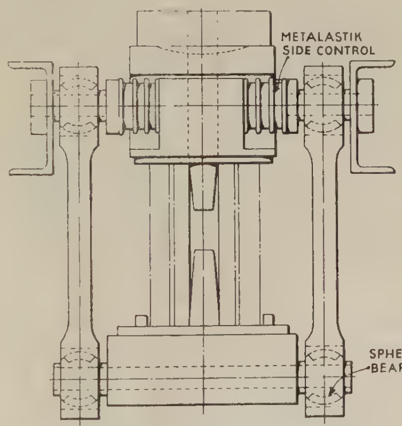


Fig 1. — Swing bolster with Metalastik bearings in the swing links and helical steel bolster springs.

to maintain with sufficient accuracy the relative position of the moving parts. Wear is eliminated, and noise transmission reduced without departure from orthodox mechanical design;

c) separation of various elements of the bogie by rubber of sufficient flexibility to absorb noise and high-frequency vibration, and prevent the transmission of small shocks. Typical examples are rubber-backed horn guides; insulating pads between bolster and underframe; and laminated spring auxiliaries. Such components act in two ways; first by attenuating sound waves, and secondly by absorbing shocks which would not be large enough to overcome the static friction of a metal-to-metal sliding surface. An arrangement like that shown in figure 2 includes all the advantages of such elements;

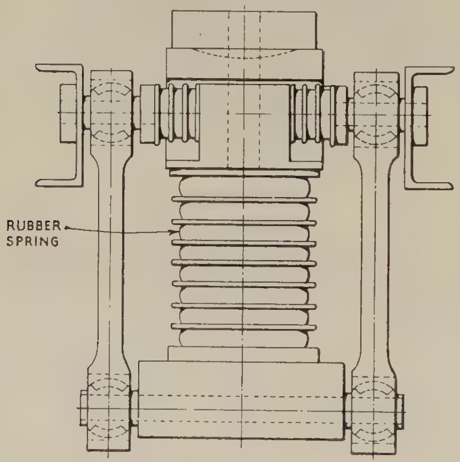


Fig. 2. — Swing bolster with rubber bolster springs and thrust blocks, and with Spherilastik bearings in the swing links.

d) complete replacement of metallic spring gear by rubber components designed from the start to suit that material's particular mechanical properties. The type of bolster springing favoured, for example, by Metalastik to replace that shown in figures 1 and 2 is given diagramatically in figure 3.

Such an arrangement can reproduce the properties of the whole of the gear shown in figures 1 and 2 with saving of the weight and complication of the spring plank and swing links. The rubber springs are very little larger than the bearing units between the bolster and cross stretchers shown in figure 1.

Many of the simpler forms of components have been in use for a long period, and have given builders and operators confidence in the performance and reliability, and have led to increased interest in all-rubber springing. Several railways are trying designs in which the bolster and axlebox spring gear is replaced completely by bonded rubber components. Most of the experience in England has been gained on London Transport surface and tube stock. Here the performance during a series of trials lasting eight years has led to an order for three prototype trains equipped with Metalastik springing. The bogies have the ordinary body bolster with roller-bearing centre pivot and roller-type side bearer. There is no present intention to depart from the type of bogie with headstocks and full-length solebars, or from the usual axle-hung motor with nose suspension on the cross stretcher.

The cylindrical bush.

The best known form of rubber bearing is the cylindrical bush in which a sleeve of rubber is retained between two metal tubes. In some forms rubber is pre-compressed and in others it is bonded. Great load capacity and reliability are given by the Metalastik Ultra-Duty bush, in which the rubber is pre-compressed after bonding to both sleeves. A typical use of such a bush in the traction link between the bogie cross stretcher and underframe of a railcar is shown in figure 4.

Such links are used with certain orthodox bogies between the bolster and solebars, where they are known as bolster anchors,

but this illustration refers to a construction in which the whole of the weight is carried on the side bearers and there is no centre pivot. The transverse swing of the bolster is accommodated by a slight torsion of the rubber and the bounce of the springs not enough load capacity with the rubber in shear.

It is quite usual to use two cylindrical bushes, one in each end of a comparatively short link; and in such cases the complete link may be moulded and bonded as a

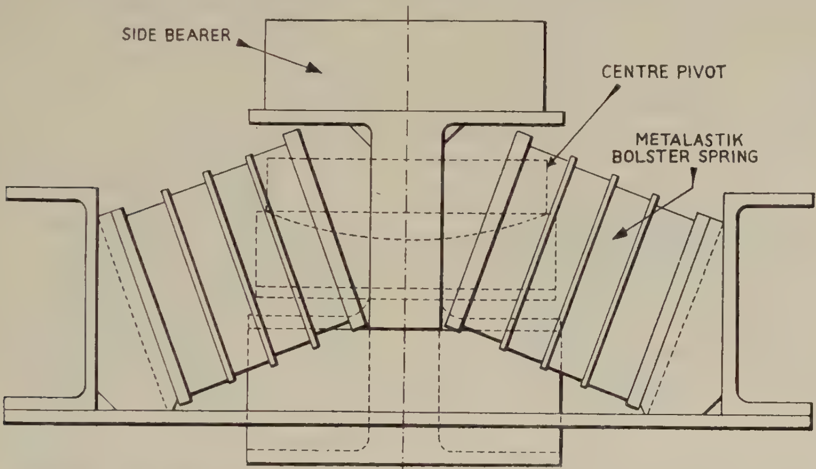


Fig. 3. — Principles of Metalastik bolster springs in inclined position.

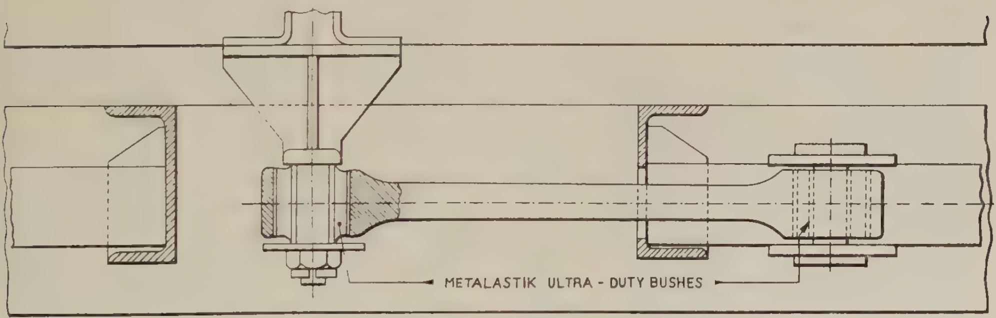


Fig. 4. — Anchor link with Metalastik bushes at the pivots, Spherilastik bearings are sometimes preferred.

by conical deflection of the rubber; but if the bush has a reasonable thickness between the inner and outer sleeves it could be turned through 90° with its axis still in the transverse plane, and work as well. The bush could not be used, however, with its axis along the link, as there is too much flexibility and single unit. This is only worth while when the whole link is of such dimensions that it can be fitted conveniently into a moulding press and the quantities are such as to justify the more expensive manufacturing equipment. In many cases the size of the bush is dictated not so much by the capacity of the rubber as by

the stresses in the pin and the general proportions of the job. It is then often allowable to bond to the inner sleeve only, and to pre-compress by expanding this sleeve when the bush is in place in the bore in which it fits. This bore may be either a sleeve or the link, bracket or other component in which the bush works, but obviously the rubber must be bonded to a simple tube which can be expanded by drifting out after assembly. In a completely bonded bush there is the alternative of pre-compressing by contraction of the outer sleeve, in which case a solid centre may be used. A rubber bush bonded with a solid pin can be forced into a hole of smaller diameter, but the amount of compression, and therefore the capacity of the bush, is limited.

A further method of achieving pre-compression is to split the sleeve into two or three sectors which are drawn back by pressing into the bore, but this method is not usually advantageous with the cylindrical bush.

Spherical bearings.

Pivots in spring gear are often required to swing about more than one axis, so that some form of spherical bearing or ball joint or its equivalent is needed. Cylindrical bushes are designed primarily for oscillation about one axis where the movement may be anything up to $\pm$ 30°. They allow some oscillation about other axes, known generally as conical movement, but the amount is usually limited to a few degrees.

When the movement about all axes is of the same order, the Spherilastik bearing is a better choice. Its principles of construction are shown in the two first illustrations. In this type of rubber bearing pre-compression is achieved by forcing the three sectors of the outer sleeve into the bore. The sectors butt up metal-to-metal, so that the pre-compression of the rubber is not needed to retain the bush in position. In addition to its universal movement, the Spherilastik bearing has the advantage of greater load capacity for the same overall dimensions than other types of bush. It is used in the swing links of the Metropolitan-Vickers bolsterless suspension.

Divided roller pivots.

In many applications such as swing hangers the load is always in the same direction, and its minimum value is at least one-third of the maximum. The types of bush described already have then an unnecessarily large resistance to angular movement; and where reduction of the resistance is important the new Metalastik divided roller may be preferable. It is similar in principle to the hinge generally used for pin joints in bridge construction, except that the pin has a bonded covering of rubber. Figure 5 shows the elements of this type of pivot separately and assembled. In the cylindrical bush the pin can be supported only at the two ends, and its diameter is determined very often by the bending stress and not by the capacity of the rubber. In the divided roller the bending stress is eliminated, and the diameter can be made as small as the loading of the rubber allows. If the location is provided in the middle, the bearing can extend right to the ends of the hinge, and can be of the greatest length that fits in the space available. The compression under load is extremely small and there is no danger of slewing to one side as a result of wear, so the divided roller pivot is particularly suitable for hangers subject to compression loading.

In the cylindrical bush, one half of the rubber performs no useful function when the load is always in the same direction; but in the divided roller, this rubber is used to give extra flexibility, as the movement is split evenly between the top and bottom coverings. If the diameter and

length were the same, the torsional resistance would be only one quarter, but in practice the diameter is made considerably less so that the resistance to swing can be reduced to a negligible amount. This may be an important advantage in hangers of which the resistance of bushes of orthodox designs may reduce the equivalent length to only a small part of the geometrical length. This device is still in the experimental stage, but preliminary tests have been promising.

Hemispherical bonded bearings.

The divided roller is intended for angular movement about one axis only

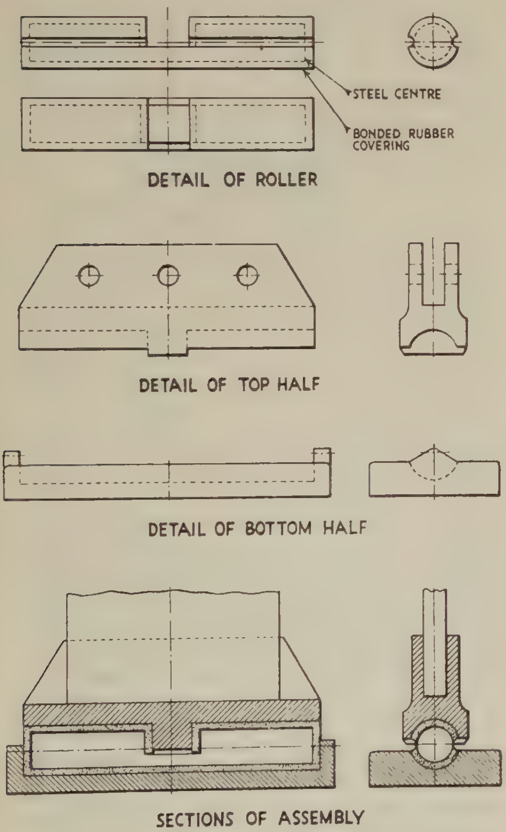


Fig. 5. — Divided roller rubber pivot, assembly and details.

and the nearest equivalent for universal movement is the type of bearing shown in figure 6.

This bearing consists only of a hemispherical layer of rubber bonded between the two metal parts; and where loadings

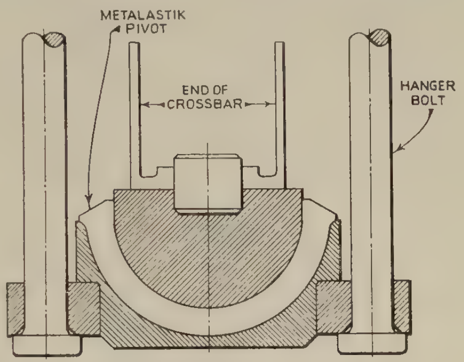


Fig. 6. — Hemispherical bonded pivot for use with substantial load in one direction.

and angular movements are moderate relative to the size it is permissible to bond only to the centre and to rely upon the compression for contact with the cup. Such a bearing is much simpler and more economical than the Spherilastik, and it gives a smaller resistance to angular movement in all directions. Its disadvantage is that it needs a hanger in the form of a bolt on either side of the bearing for which the space is not always easy to find. A similar bearing can be made in the form shown in figure 7 when the single central bolt is much easier to accommodate. On the other hand, the size of the bearing is increased considerably because the central hole takes away the part of the rubber which would otherwise be most completely trapped and offer the major part of the resistance to compression. It may be necessary, therefore, to increase the load capacity by including intermediate metal plates in the way shown in figure 7. These resist the tendency of the rubber to bulge at the free edges.

Disc type mountings.

A usual practice is to mount bolster anchors and similar links on circular mountings which may with advantage be bonded and fastened in the way shown in figure 8. The rocking of this sort of mounting is, in theory, the wrong way of accommodating pivotal movement; but when the forces along the link are large and the angular movement small satisfactory results are obtained. This type of assembly can be attractive by reason of its simplicity and ready adaptation to adjustment of length.

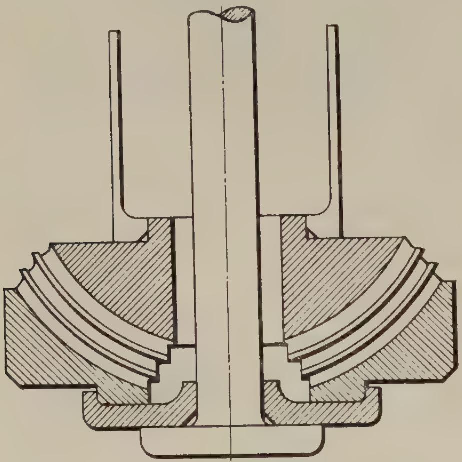


Fig. 7. — Spherical seated pivot with centre hole.

Flat-plate mountings.

Some mountings are designed to allow a certain amount of relative plane movement between two parts to replace sliding. The same result can be obtained by using a long link with bushes at the ends, but more often the flat mounting is chosen by reason of its simplicity and more compact shape. Use is made, in these mountings, of the fact that rubber, although so flexible in shear, is almost incompressible in volume, when it is bonded to opposing metal plates. Reduction in the space between them can take place only by bulging of the free surfaces which amounts to very little movement indeed when the thickness of the rubber is small compared with the area of the bonded face. Bonding is essential to obtain full advantage of this property. If the rubber is simply pre-compressed it can slide over the surfaces of the plates, giving a much larger deflection. The nearest approach to frictionless sliding is given when the ratio of compression stiffness to shear stiffness is the highest, and for that purpose inter-

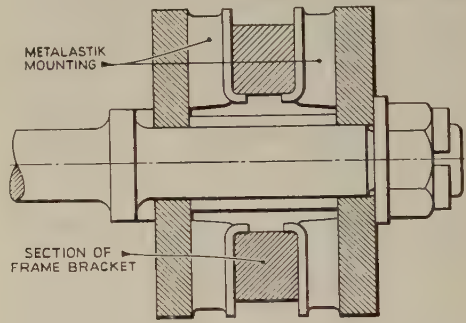


Fig. 8. — Disc type pivot with anchor link.

mediate metal plates are a good thing. They have the further advantage of reducing the size and weight of the bonded unit; but in some cases it is required that the mountings shall have a definite stated resistance to shear movement.

For application to a heavy Diesel-electric locomotive with the type of swing bolster layout shown in figure 1, the part shown in figure 9 was evolved. One of these is placed on each side of the bolster and the two are pre-compressed against one another by set pins and retained by slotted packing pieces. There is a limit to the value of the thickness of the mounting which can be allowed with any given diameter or width. If the thickness is made too great in an effort to achieve a lower shear rate, it may be found that the pre-compression causes the mountings to have an actual negative stiffness, that is to give a

load away from their normal position instead of towards it. Plate-type mountings proportioned to give negative stiffness distort in the manner shown in figure 10; that is to say the deflection takes the form of bending rather than shear, and the assembly of the two mountings and the bolster becomes a buckling strut. If the deflection of the mounting must be in a ratio to its size which would cause such an effect, then the solution is to divide it into two stages, with the intermediate plates tied together in the manner shown in figure 11.

The tied intermediate plates do not interfere with the proper shearing movement of the rubber, but prevent the inclination of the centre of the mounting which is the cause of the buckling.

Similar but larger mountings are used in other locomotives directly between the bogie frame and the underframe. In this case, the whole weight of the superstructure is carried by rubber in compression while the mountings shear to allow the bogie to negociate curves. The arrangement is shown in figure 12. It is not an easy matter in this case to make the springs of such proportions that they are free from negative stiffness, and tying together of the intermediate plates across the bogie is not usually practicable. Since the size of the rubber spring must bear a certain relation to the movement, this device, like many others using directly-loaded rubber, appears to much greater advantage with heavy loads than with light loads. The bogie shown here has a fixed centre pivot, and there might be difficulties in adapting this design to the

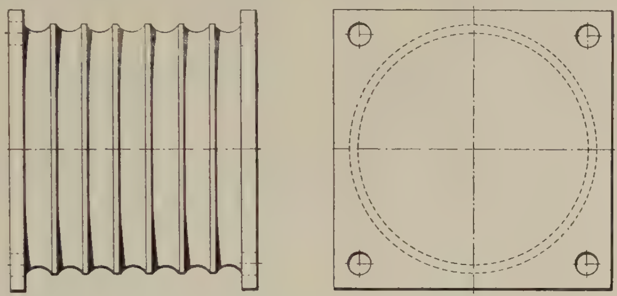


Fig. 9. — Heavy duty bolster control spring as used in large Diesel-electric locomotives.

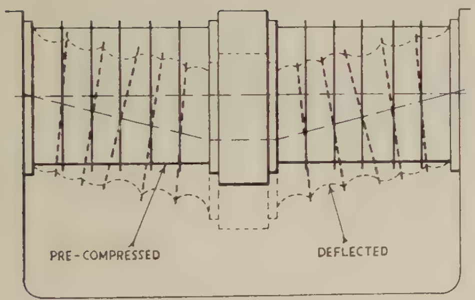


Fig. 10. — Proportions of spring with negative stiffness.

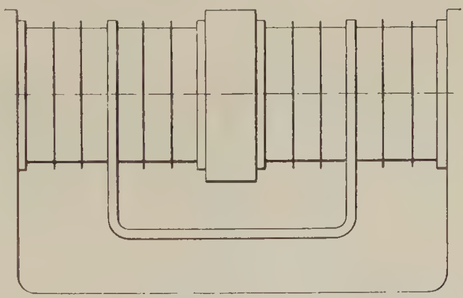


Fig. 11. — Stabilisation of intermediate plate in spring.

larger movement required with a centre pivot having transverse flexibility to simulate the swing bolster. Generally speaking, the maximum ratio of compression stiffness to shear stiffness possible in designs like those shown is 50 to 1. Many sliding bearings require much smaller movements than those noted above, and then

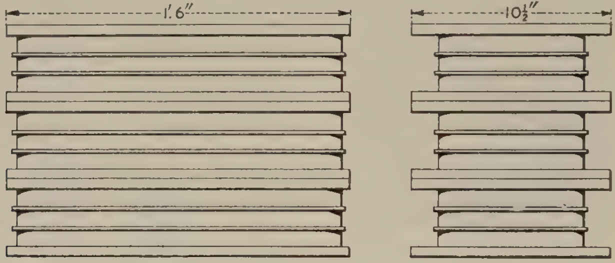


Fig. 12. — Rubber side bearer of heavy Diesel-electric locomotive.

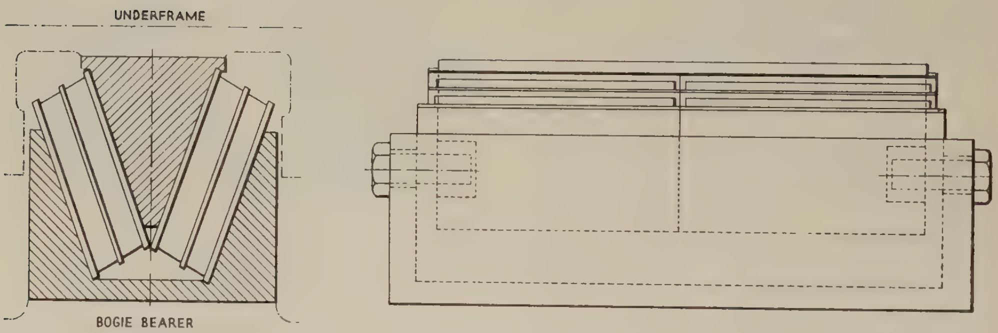


Fig. 13. — Side and end bearers of bonded rubber for bogie locomotive.

it is possible to use simpler mountings either without intermediate plates or with only one or two. Sometimes it is good design to make the mounting deliberately large and of comparatively soft rubber to get a better ratio of compression to shear with a simple construction.

The design shown in figure 12 is a special form of side bearer, but many are in use in which the rubber is essentially a spring, and the sliding surfaces, often unlubricated, are retained.

Side and end bearers.

A design that has been in use for some years is shown in figure 13. This had to be proportioned to suit the space which was occupied previously by a metal spring side bearer, which was not entirely satisfactory. The bogie is not of the swing-bolster type, and is used on a powerful locomotive. The greater part of the weight is carried ordinarily on the centre pivot, but the side and end bearers carry a part, and their main function is to reduce the weight transfer under traction loads, thus retaining sufficient adhesion on all axles. The normal loading of the side bearer shown is 6 tons and the deflection from the free position $^{7}/_{16}$ in. A lubricated surface is used, but the housing prevents the oil from coming into contact with the rubber.

This side bearer is a typical example of the use of Metalastik mountings in a V, that is, loaded partly in shear and partly in compression in such a way that the compression thrusts are balanced within the spring assembly. Rubber, when subjected to shear movements, gives the best durability if it is pre-compressed, and when the loading is always in the same direction it is economical to use the pre-compression to provide part of the reaction. Generally speaking, about half the load can be supported by the compression and half by the shear of the rubber, so that the use of Metalastik springs in a V reduces by half the amount of rubber used. In this case, the space was limited and the maximum possible resistance had to be derived from the compression of the rubber which results from the wedging action. The resistance is doubled by the use in each Metalastik bonded mounting of one intermediate metal plate; but if there were plenty of space it would be better to use a simpler and rather larger mounting with no intermediate plate. No allowance need be made in this design for reverse loadings, but the assembly is retained so that it does not fall to pieces if the superstructure is lifted from the bogies.

Rubber side bearer.

If a rubber side bearer had been included in the design from the first, a slightly different construction could have been installed advantageously, along the lines shown in figure 14.

Here the circular Metalastik mountings are arranged round a cone so that their axes of maximum stiffness intersect nearly in the centre of the sliding surface, which may well be of asbestos, needing no lubrication. There may be three or four circular mountings in the assembly, whichever is more convenient for the particular job. By arranging the mountings in this manner there is little tendency for the friction pad to tilt when it slides and uniform loading is maintained. When a lubricated bearing is preferred, a synthetic rubber oil-proofed cover can be fitted between the inner and outer castings. The bonded mountings are retained in place entirely by the loading and need not be bolted to the castings. There is a guard washer above the top casting to prevent the assembly from falling to pieces when the carriage is lifted. Side bearers of this type can be made conveniently for loads up to 16 tons.

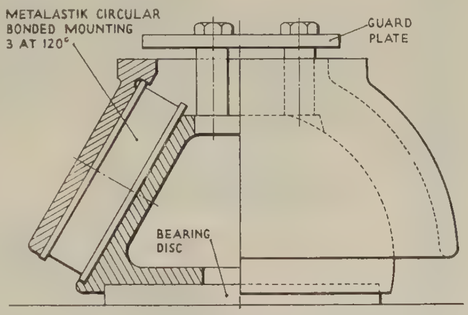


Fig. 14. — New design of Metalastik side bearer.

Rubber compounds as developed up to the moment do not always have sufficient internal energy absorption; and where a complete bolster suspension system is of the rubber type some additional damping means may be needed to give the effect of the frictional surfaces in conventional bogies if a build-up of excessive amplitudes at critical speeds is to be avoided. This has been done in certain bogies by the insertion of a self-adjusting friction plate between two rubber springs, which are themselves slightly offset one to the other in regard to their centre lines.

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